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AN EXPLORATION OF SOLAR - DIESEL HYBRID IRRIGATION SYSTEM IN BANGLADESH

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Abstract*-The solar energy is a vital concern of renewable energy among conscious generation due to the exiguity of coal, oil and gases like conventional energy. Referable to the profusion of solar power, solar irrigation system is an alternative solution of irrigation system, but due to reliance on sunlight, higher initial cost and long payback period the system is not viable. Solar - diesel hybrid system will solve this problem and increase the yield. This paper presents the prospects of solar - diesel hybrid irrigation system with both technical and financial point of view. In prevailing solar irrigation system PV panel is used to produce dc current and by the inverter the dc current is converted into ac current and finally operates ac pump to lift water. The hybrid system run via both renewable and nonrenewable cradles which makes conceivable to increase more than 8 to 12 operating hour per day and eventually reduce 5 years to achieve the investment. Though it's not putting back the total conventional energy for irrigation system, however a plentiful amount of energy will save to cultivate agricultural land in Bangladesh with promising cost and supply water continuously while off sunshine.*

Keywords: Solar, Agriculture, Renewable, Diesel, Hybrid.

1. INTRODUCTION

The renewable energy is a vital concern among conscious generation due to the exiguity of coal, oil and gases like conventional energy. Referable to the limited resources of fossil fuel it is better to replace the conventional energy to renewable energy. Bangladesh is not far behind along compare with other nations. It has already introduced with various sources of renewable energy. Solar, hydro and wind are the main renewable sources of energy in Bangladesh. Bangladesh is primarily an agrarian country and huge amount of power needed to supply water in the agricultural sector. The entire contribution of the farming sector to GDP is 19.29% and crop sector to GDP is 13.44%.Just about 47.5% of total man power relies in agriculture sector [1].This agriculture sector has an impact in getting employment, alleviation of poverty, as easily as food security. Hence the agricultural sector receives a great importance in a producing nation like Bangladesh. The total arable land in Bangladesh is 8.52 million hectares in which the total cropped area is 14.943 million hectares. These large amount of lands is cultivated by 2,66,000 irrigation pumps which are being maneuvered by the electricity [2].These irrigation pumps consume about 1300 MW of electricity, which is roughly 25% of the entire output of the land [3].It is a problem for Bangladesh to supply the desire quantity of electricity for irrigation as the country experience unmanageable gap between provision and demand of electricity. Load shedding seems intolerable in Bangladesh, especially in the summer season during which there is huge demand of electricity for irrigating the ground. At present the electricity generation capacity in Bangladesh is 6500 MW. Only about 47% of the total population of Bangladesh are able to use electricity. Moreover the unavailability of grid electricity in rural area causes great hamper for cultivation. It diminishes the production and likewise decrease the country GDP and creates food crisis. Beside electricity, diesel is another sources of fossil fuel to control the irrigation pump. In Bangladesh recently exhausts average 0.9 million loads of diesel per year to operate nearly 1.34 million diesel run irrigation pumps [4].

For secure and green fourth coming milieu it is advocated to employ renewable energy in this agricultural sector. Bangladesh situated between 20° 34´-26° 38´ north latitude and 88° 01´-92° 41´ east longitude [5]. The solar radiation effect in this area is more effective and it varies between 4 and 6.5 kWh/m^2. Thus the solar energy acts as an important function in this region as renewable sources. Recently in 2010 the solar power is widely used for irrigation in Bangladesh. Yet, as obstacles such as cost and efficient means, the renewable

sources provide about 3 to 5 percent of energy needs in Bangladesh [6]. Referable to the profusion of solar power and geographical benefit the practice of utilizing solar energy is augmenting. Solar irrigation system is the accomplishment of solar energy which creates an alternative solution of irrigation system in the agricultural sector of Bangladesh. 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 a 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 gain profit from the project and cultivate more land in the area [7].

Straight off a day's hybrid irrigation system is employed in various states all over the globe. Hybrid power system is a compounding of different sources of producing electricity that confirms the uninterrupted provision of electricity. Generally wind solar hybrid energy system is used most of the country for irrigation sector [8]. Though the hybrid scheme is an admirable sources of renewable energy which release the gravity of conventional energy and retain the environment green. It is not so much popular for its exorbitant installation cost and dependent on the wind speeds for its geographical placement. But on the other side 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, but it is valueless in these locations where grid electricity is not reached. In Bangladesh the rural region is a principal concern to cultivate crops, hence it is important to make the backup system of irrigation without the grid electricity and also cut the diesel fuel [9].This paper presents the exploration of solar - diesel hybrid irrigation system in Bangladesh. For this, both technical and financial analysis of the solar irrigation system and diesel connected pumping system is considered and finally combined the analysis of 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 the prospect of the hybrid solar irrigation system.

2. METHODOLOGY

The methodology was occupied to find out the exploration of solar – diesel hybrid irrigation system in Bangladesh is concise here. At first the area was selected at where the solar irrigation system and diesel fuel operated 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. Lastly, compare the financial improvement of the solar – diesel hybrid irrigation system after solar irrigation system.

Fig.1: Solar irrigation project at Godagari, Rajshahi

3. STUDY AREA

The work region was chosen based on the districts where the solar and diesel fuel operated pump running at least several years. By these, three districts were selected namely Rajshahi, Naogaon and Jessor. In Rajshahi there are approximately 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 which shown in Fig. 1. 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. 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. On the other hand diesel fuel operated pump is used all over the country. For the analysis same district is considered.

4. TECHNICAL ANALYSIS

Solar - diesel hybrid irrigation system is an upgrading system of the existing solar irrigation system. In this system, both the solar energy and diesel fuel are used simultaneously as alternative authors. Solar system directly depends on the sunshine and the irrigation project is shut down at the off sunshine. So it hampers the supply water as well as production of crops. Diesel fuel can used in that situation when solar system is in downstream. It's also noticeable that the only diesel irrigation system is not suitable for the environment. So for reduction the use of diesel fuel and replaced conventional energy into renewable energy as well as cost effective solar diesel hybrid irrigation system will better option for this time. For the analysis solar irrigation pumping system and

diesel fuel operated pumping system is considered separately. Finally proposed the improved solar diesel hybrid irrigation system which reduces the conventional energy and also the running cost.

4.1Solar irrigation system

Solar irrigation system is the application of solar energy. 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. Finally a submersible AC pump is running by using this AC current [10]. The diagram of the solar irrigation system shown in Fig.2. 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 more eminent than the pump power to operate the pump uninterruptedly. The irrigation project at Chowgacha in Jessor is considered in the comparative analysis. The corresponding technical parameter of solar irrigation project is shown in the Table 1.

Table 1**:** Solar irrigation project specification

Parameter	Unit	Value
Maximum power	kW	11.84
Panel number	no.	55
Per panel capacity	W	215
PV array area	m^2	79.8
Pump head	m	30

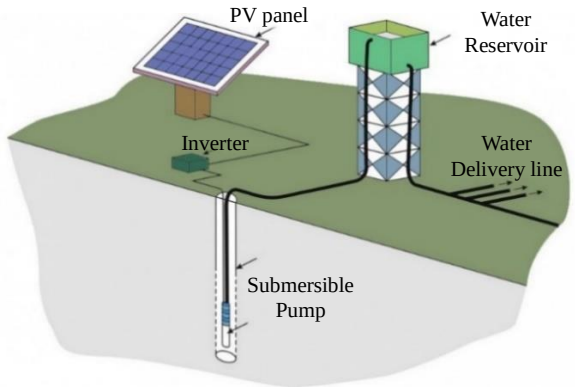

Fig.2: Diagram of Solar irrigation project

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.

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

By using the equation (1) the overall efficiency found about 16.47% for 11.84 kW power supply to the pump. It may vary from system to system for different PV array area, solar radiation and per panel capacity. The mean solar irradiation of the visited area is assumed 4.85 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.

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

The Liter per Wp for this system was calculated by the equation (2) and it was found 9433 for a year when the discharge was 600 L/min and the average operating time was 8 to 9 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	8-9
Flow rate	liter/min	600
Average water supply	liter/day	2,50,000
Litter watt peak	liter/Wp/y	9,433
Average solar radiation	kWh/m^2	4.85
Overall efficiency	%	16.47

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.

4.2Diesel fuel irrigation system

Diesel irrigation system is one of the oldest and most popular in rural area in Bangladesh. In this type of irrigation system diesel oil is used as an operating fuel. It has two sub system one is power subsystem and another is pumping subsystem. The diesel engine is included in the power subsystem and the diesel engine run through the diesel oil. On the other hand the suction pipe, delivery pipe and impeller are in the pumping sub system. The engine shaft connected with the impeller. The pump impeller driven by the drive shaft of the engine and rotated the impeller. Thus lifted water from the ground and supply water for irrigation. The primary advantages of the diesel irrigation system are that it has no need to any electricity supply and hence can be easily installed in everywhere. The corresponding information of the diesel fuel irrigation system is presented in Table 3.

Table 3: Diesel fuel irrigation project information

Parameter	Unit	Value
Pump capacity	HP	10
Head of pump	m	25
Discharge	liter/min	450
Operating time	hour	16
Fuel consumption	liter/hr	1.25-1.50

By the survey it was establish that the discharge of the

pump varies from 350 to 600 liter/min and the ticker is in operation about 16 to 20 hours according to requirement. In rural area where electricity is not available, there diesel fuel irrigation system support the irrigation system. Farmers used diesel pump for irrigation purposes in these areas because of insufficient grid power or higher cost of electricity. But it has a harmful effect on the environment. It emits 2.68 kg CO_2 per liter of diesel. Therefore it is desirable to reduce the usage of diesel fuel and find out the alternate energy solution [11].

4.3Solar - Diesel Hybrid Irrigation

The solar - diesel hybrid irrigation system is an advance method of irrigation system rather than solar irrigation system. Though the solar irrigation system is a noble practice of renewable energy, but the main difficulties are the longest payback period and less operating time comparable to other method of irrigation system. On the other hand the diesel fuel operated irrigation system used up a large amount of conventional fuel. For the limited resources of fossil fuel it is high time to reduce the conventional energy and find out the renewable energy sources. The hybrid solar - diesel irrigation system will be the solution for reducing the uses of fossil fuel and also minimize the major problems solar irrigation system [12]. The proposed hybrid solar irrigation system are shown in the Fig. 3.

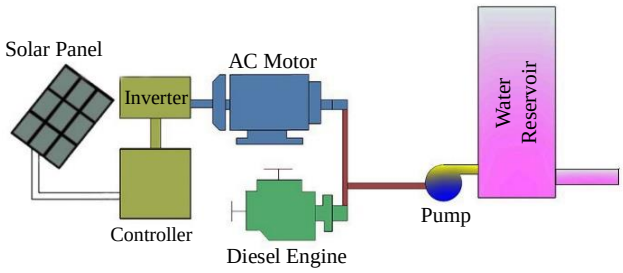

Fig.3: Solar - diesel hybrid irrigation system

In solar - diesel hybrid irrigation system the task consists of two units, solar is one unit which is renewable sources of energy and other unit is a diesel engine which is working from the diesel oil. The two units are combined with the shaft and pulley and finally connected to the impeller to run the pump. In solar unit the DC current is converted into AC current by the inverter and run the AC motor to raise water. On the other hand, in diesel engine unit diesel fuel run the engine shaft and lift water through the pump. The two units are working separately, at full sunshine the irrigation system is run from the renewable sources but when it is failing to supply such power to run the pump that time diesel engine supported the supply of water. It found that the average sunshine in the Bangladesh is about 8 to 10 hours per day and only this time solar energy can utilize for the irrigation. While the other 14 to 16 hours the solar energy cannot use without any battery storage. 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. This increase the 8 hour operating time and remaining time of the day it should keep idle for better life of the pump. The solar - diesel hybrid irrigation system will increase the operating time in existing solar irrigation system so this project will more viable and profitable.

5. ECONOMIC ANALYSIS

A project is acceptable when the project is financially viable. Besides the technical improvement it is another concern about optimization the cost. Though using renewable energy is relatively higher than other sources, but the cost need to moderate for public usage. In solar irrigation project the installation cost is much higher than others. The initial cost of different irrigation project is shown in Fig. 4.It is found that the solar irrigation project installation cost is 40 lakh BDT while diesel irrigation project installation cost is merely 37 thousand BDT. On the other hand electricity generated irrigation project cost is above 2.5 lakh BDT. Referable to the higher initial cost of solar irrigation project, now a day these types of tasks are established by the government and non-government association. Though the solar irrigation system is an alternative sources for irrigation but for its high investment cost it is not suitable for the investment and it is also hard-hitting to recover the total investment earlier in its project life time. Therefore the solar - diesel hybrid irrigation system may be a good prospect to recover the investment within a shortest possible of time and noticed that the existing solar irrigation project can convert into solar - diesel hybrid irrigation project within an additional fifty thousand only.

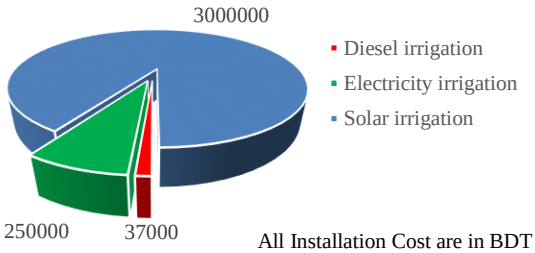

Fig.4: Installation cost of various irrigation system

In terms of economic analysis, both the solar irrigation project and diesel fuel running irrigation project was considered and finally estimate the analysis of solar - diesel hybrid irrigation system. For economic analysis Net present value (NPV), Internal rate of return (IRR) and simple payback period were calculated both for solar irrigation and solar - diesel hybrid irrigation system. The exploration 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 per bigha paddy is 1750 BDT per season. On the other hand, in the diesel fuel running irrigation system water supply charge for paddy per season is about 3000 to 3800 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 per bigha running costs and 1800 BDT for diesel fuel cost. The difference running cost for per bigha paddy and their corresponding charge is shown in the Fig. 5.In a diesel fuel irrigation system per liter diesel cost is around 70 to 72 BDT while solar is absolutely free in terms of carrying costs. So in hybrid system the diesel unit acts as a backup unit which operate entirely when the solar unit is done in service.

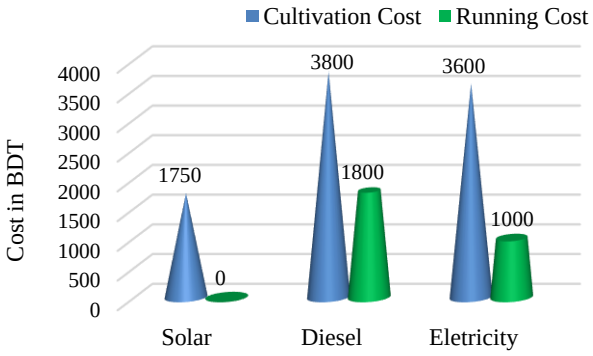

Fig.5: Cost of per bigha paddy in different sources

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 [13].In the Table 4 for the different discount rate the NPV is shown for both the solar irrigation project and solar diesel hybrid irrigation project. From field visit feedback these economic 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 striking in the hybrid solar irrigation system added the extra installation cost for a diesel engine and assembly to pump.

Table 4: NPV of the project

Discount Rate	Solar irrigation	Solar - Diesel Hybrid irrigation
2.5	305,751.08	3923888.39
7.17	-	2039521.817
8.4	-	1265858.431
8.61	-	788426.0538
10.29	-	713607.7337

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. 6 denoted the discount rate where the NPV is zero that point is considered as the project IRR.

Besides the NPV and IRR the simple payback period is the vital term of the project financial analysis and it should be minimized as possible. The IRR and simple payback period are shown in Table 5.

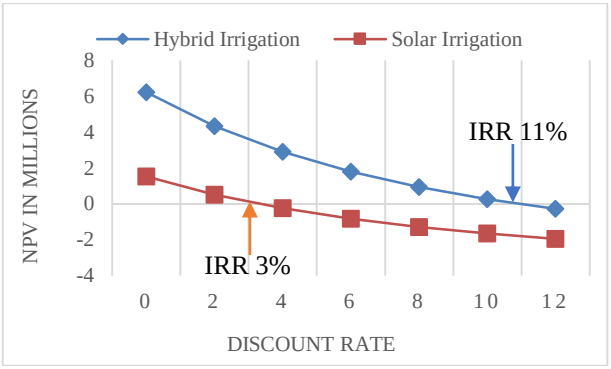

Fig.6: NPV vs. Discount Rate

In solar irrigation by the survey report, assumption and analysis the simple payback period is about 14.58 years and while improving the solar diesel hybrid irrigation system the simple payback period is reduced at 7.02 years only. Thus in the hybrid solar irrigation the simple payback period is decreased 6 to 7 years from the existing solar irrigation project.

Table 5:IRR and simple payback period

Parameter	Solar Irrigation	Solar Diesel Hybrid Irrigation
IRR (%)	3	11
Simple Payback period (y)	14.58	7.02

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

6. CONCLUSIONS

Bangladesh has an enormous dependency on agriculture and for the irrigation purpose water is obligatory. The grid connected irrigation project hastens energy crisis and diesel fuel operated irrigation project diminishes the reservation of fossil fuel. But the solar diesel hybrid system reduces the energy crisis as well as relying on fossil fuel in moderate rates. The ultimate exchange is summarized in the observing stages:

a. Solar irrigation is a practice of renewable energy which reduce the dependency on electricity as well as diesel fuel.
b. The average efficiency finds 16.47% in terms of solar energy.
c. Solar irrigation project is not financially viable due to high initial cost and less operating time. Such as 30 to 50 lakh BDT is required for installing a 10 HP solar pumping project.
d. The simple payback period is found 14.58 years and operating time is around 7 to 10 hours per day in the solar irrigation system.
e. But in solar diesel hybrid irrigation system the simple payback period is found 7.02 years, which reduce up

to more than 5 years to return the investment and operating time increases approximately 8 to 12 hours per day.

f. Afterward introducing solar diesel hybrid irrigation the NPV and IRR are also increased and simple payback period is decreased than solar irrigation system.

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

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8. NOMENCLATURE

Symbol	Meaning	Unit
A	Surface area of panel	m^2
I	Solar radiation	kWh/m^2
t	Operating time	hr/day
P_1	Pump power	kW
P_2	Panel power	kW
Q	Flow rate	liter/min
η	Overall efficiency	%
W_p	Watt peak	W
L_p	Liter per watt peak	liter/Wp/y