Feasibility Study of RE Simulation Software: A Comparative Financial Study between Enhanced PV Solar technology and Diesel based Irrigation System

Md Rabiul Islam, Md.Moslem Uddin, Atik Faysal, Pronob K. Ghosh

Abstract— **Bangladesh is an agricultural country. One-third land of this country is in off-grid area which force farmers to use diesel for irrigation purpose. Several research works show that PV Solar technology is useful for irrigation system rather than conventional fossil fuels using various simulation software. But the ambiguities arise to select simulation software for techno-economic analysis. This study identifies the effectiveness of RE simulation software for techno-economic analysis and compare the benefits between PV Diesel and solar PV based water pumping system. The efficacy of mostly used RE simulation software will be analyzed to study financial feasibility of solar PV based water pumping system comparing to Diesel based system assuming a practical project in Bangladesh (a Bangladeshi farm named "Rajshahi Krishi Khamer"). This farm is now using Diesel based water pumping system for irrigation. Two contemporary and essential software, HOMER (Hybrid Optimization Model for Electric Renewable) and RETScreen are used to demonstrate the case studies. Some important issues about solar as well as Diesel based water pumping system are taken into consideration to accomplish this research work. The proposed studies also count the technical and environmental effects and eventually, address alternative sources of electric power generation.**

Index Terms— **Diesel, Economic Feasibility HOMER, Photovoltaic Water Pumping, RETScreen , Solar Pump.**

I. INTRODUCTION

Bangladesh, officially the People's Republic of, is a country in South Asia. It is bordered by India on all sides except for a small border with Burma (Myanmar) to the far southeast and by the Bay of Bengal to the south. Bangladesh has the highest population density in the world with a land area of 147,570 square kilometers, remarkably ranked 11th in the world. Bangladesh's population range from 150 to 170 million, making it the 8th most populous nation in the world. Bangladesh is an agricultural country with 14.943 million hectare agricultural land. Bangladesh has also so many farms (Livestock and poultry farms). To meet up food demand of growing population and animals is one of the challenging tasks for Bangladesh. In agriculture system, irrigation cost is increasing day by day due to higher cost of diesel price though electricity based irrigation system is present.

Md Rabiul Islam, B.Sc. in Electrical and Electronic Engineering from RUET, Bangladesh.

Md. Moslem Uddin, B.Sc. Engg. degree in Electrical and Electronic Engineering with obtaining 4th position in order of merit from PUST, Bangladesh

Atik Faysal, B.Sc. Engg. degree in Electrical and Electronic Engineering from PUST, Bangladesh in 2017

Pronob K. Ghosh, B.Sc. Engg. degree in Electrical and Electronic Engineering from PUST, Bangladesh in 2015, M.Tech. degree in Power System Engineering from NIT Agartala, India in 2017

Bangladesh's installed electric generation capacity was 12,180 MW in 2016; only three-fourth of which is considered to be 'available'. Natural gas is the main source of electricity production in Bangladesh [1]. Shortage of natural gas will rise day by day until new fields are discovered. To maintain continuity of Power (Electricity) supply with this shortage amount of gas, some other consumers (Industry and domestic) are completely shut off during peak demand of electricity.

For this reason Bangladesh is importing oil which impacts on our economy. Demand of electricity for irrigation purpose is also a burden for Bangladesh. Most of the farmers are using diesel based irrigation system due to shortage of electricity. Not only Government but also other developing partners are also trying to find out alternatives to meet up energy demand.

A substantial amount of research works on the advantageous aspects of application of non-conventional sources, for instance, solar power, wind turbine etc. over conventional fossil fuel based sources, such as, oil, gas etc. for electric power generation have been addressed previously. In [2], a financial analysis on PV based watering system in Bangladesh was conducted couple of decades ago. However, the research result showed that, according to the contemporary price level, PV based watering system was not advantageous to other conventional options, for instance, Diesel based watering system.

Now-a-days solar based watering system with superior technologies are being used, some of which have been addressed in [3-4]. Hence, these pioneering solar technologies helps to reduce the irrigation cost significantly. Researchers are applying these advantageous criteria in irrigation system of different remote parts of the world to make this system more feasible. For instance, in [5], a PV based viable water pumping scheme for a remote part of Ethiopia has been introduced.

In addition, solar based watering scheme for the remote distant areas has also been presented in [6]. Environmental issues have been considered in this paper as well. A feasible cost effective PV based water pumping structure have been addressed in the perspective of India in [7]. After being motivated by these studies, a financial comparison has been conducted in this paper to overcome the previous drawbacks relating to the irrigation in Bangladesh. Furthermore, in the aim of finding alternative energy resources, this research work has also addressed about how PV based water pumping system will meet not only energy demand but also cost efficient. Rest of the paper has been shaped as follows.

Section 2 elaborates the project configuration which has been considered to justify the efficacy of the proposed

method. The methodologies has been interpreted in section 3. Then, section 4 describes the result analysis. Finally, section 5 concludes the paper.

II. Project Description

To demonstrate the proposed methodology study one of the farms of Bangladesh named "Rajshahi Krishi Khamer, Bangladesh" has been selected. Presently, this farm is using Diesel based water pumping system for their irrigation. The economic feasibility study of different systems (Diesel and RE-Storage) will be analyzed here. Though RE based sizing and financial study was carried out by using simulation software HOMER, RetScreen, PV System etc. In this research, sizing, financial study of these systems will be done by using HOMER and RETScreen simulation software.

Though Bangladesh belongs to a developing country the power sector of this country is still lagging behind. The industrial production as well as domestic life is suffering for the shortage of power. With only about half of Bangladeshis have electric facilities and the per capita energy use is only 180 Kilowatt-hours, which is one of the lowest in the region [8]. However, Bangladesh have good potential of renewable energy resources [9]. To accomplish this research work, two possible water pumping systems are considered for irrigation – diesel based watering system and the non-conventional solar based watering system. Details about the project are given bellow:

Name: Rajshahi Krishi Khamer, Bangladesh.
Location: Rajshahi, Bangladesh (24.4°N, 88.6°E)
This Krishi Khamer consists of 60 cattle's, 100 sheep's, 100 goats, 2000 hens, 1000 ducks and 1.8 hectors of agricultural land. Table 1 & 2 show present water pumping system details:

Table 1: Water Pumping System in Rajshahi Krishi Khamer

Items	Measurements
System head	4.95 meters
Water Requirement	156.2 m^3 per day
Power of the engine (horse power)	6 hp.
Cost of the engine	$818
Life time of engine	10 years
Cost of pump	$114
Life time of pump	10 years
Consumption of fuel per horse power per hour	0.21 liters
Cost of diesel per liter	$1.15
Number of working hours (pump used for only 3 hrs. per day)	1095
Total Fuel Cost per year	$1,379.70
Operator`s salary per month	$100
Maintenance cost per year	$91

The following drawbacks of Diesel based water pumping system have been considered here-

- The price of Diesel is increasing significantly with diminishing its' availability, whereas the price of PV components are decreasing with the development of solar technology.
- Aged Diesel engines consume more fuel than expected as efficiency decreased.

Transportation and storage of fuel also a burden for them

Table 2: Water Pumping System in Rajshahi Krishi Khamer

Costs	Items	Amount
Capital	Pump	$114
	Engine	$818
	Accessories and installation	$550
	Total capital cost	$1,482
Running Cost	Operator`s salary per Year	$1,200
	Fuel and lube oil cost per Year	$1,379.70
	Maintenance cost per Year	$91
	Replacement cost (for engine)	$818
	Replacement cost (for pump)	$114

.

With the aim of finding alternative energy, the metrological data, which is given in Table 3, is analyzed and observed that solar energy potential can be an alternative energy solution for them.

Table 3: Metrological data of Rajshahi, Bangladesh

Month	Air Temperature	Relative Humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature
	°C	%	kWh/m²/d	kPa	m/s	°C
January	17.6	53.5%	4.35	98.9	2.3	19.1
February	20.6	47.6%	5.22	98.7	2.5	23.0
March	24.6	46.8%	6.10	98.3	2.6	27.6
April	25.6	65.9%	6.20	98.1	2.5	27.9
May	26.2	78.4%	5.74	97.8	2.4	28.0
June	27.0	84.6%	4.77	97.5	2.3	28.1
July	27.0	86.7%	4.19	97.5	2.1	27.8
August	27.0	85.3%	4.29	97.7	2.0	27.8
September	26.0	84.8%	3.89	98.0	1.9	26.7
October	24.0	78.6%	4.67	98.4	1.9	24.4
November	21.0	67.6%	4.66	98.7	2.1	21.1
December	18.6	57.9%	4.26	98.9	2.2	19.2

By using solar potential, the sizing of PV and storage system instead of Diesel have been done here. By varying PV Module size and Battery size, suitable combination of PV & Storage system based on their cost are achieved.

III. Proposed Methodology

To design water pumping system with PV-Storage/ PV-Diesel, HOMER and RETScreen Simulation Software have been chosen. National Renewable Energy Laboratory in the United States developed HOMER simulation software. It is used to design and evaluate financially and technically the options for on-grid and off-grid power systems for remote,

stand-alone and distributed generation applications. It also gives us additional information's e.g. financial benefits after integrating renewable energy source, CO_2 emissions etc. RETScreen also clean energy management software authorized by Natural resources Canada. It is used as a decision support tool. It is popular for analyzing financial feasibility for various types of renewable-energy and Energy-efficient Technologies (RETs). It also offers various tools for different types of load inputs which is not possible by other simulation software e.g. thermal load, Hydraulic load etc. An exceptional overview of this software has been provided in [10] which was used for modelling a Photovoltaic project.

This research work follows bellow mentioned steps to analyze suitable and efficient energy source for water pumping system:

- Rajshahi Krishi Khamer, Bangladesh requires 157 m^3/day water with system head of 4.95 m. It is necessary to convert Hydraulic Energy to Electric Energy. To design this the efficiency of motor-pump set is considered as 40 % and DC form of electric energy is taken into consideration. Simulation software RETScreen is used to design this system.
- Number of PV module and Battery will be optimized based on Electricity Demand and Solar irradiance. For design purpose, different variables (number of PV & Battery size, their investment, operational and maintenance, replacement cost, project life time, Motor-pump's cost, operational hours) will be given to both of the simulation Software - HOMER and RETScreen.
- Comparison of both Simulation results is obtained by HOMER and RETScreen in order to understand the performance of both simulation software.
- Feasibility study of proposed PV-Battery based project with existing Diesel system.

IV. Result Analysis

Rajshahi Krishi Khamer, Bangladesh requires 157 m^3 water per day with system head 4.95 m which is equivalent of 5.25 kWh/day as shown in Fig- 1.

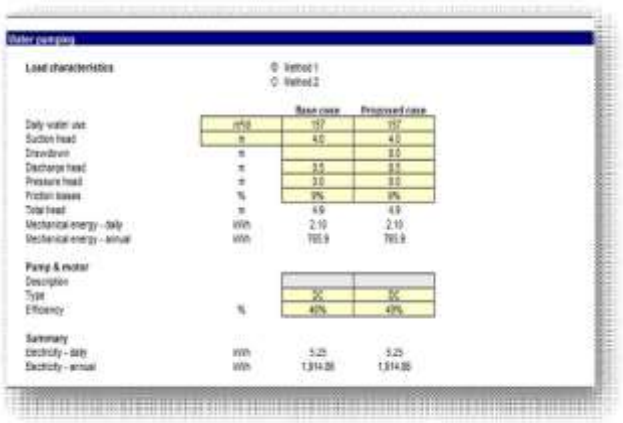


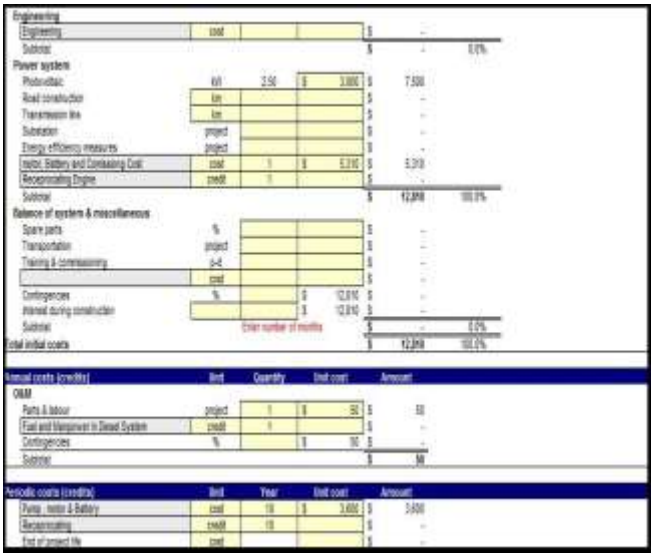
Fig.1 Load characteristics of water pump

Optimization and sensitivity analysis of this research work are analyzed by different number of Battery and PV size as shown in Table 4. The PV module and Battery specifications, and project costs are also mentioned in the Table 4 and 5.

Table 4: Component Details of PV-Battery system

PV	Battery
Total Capacity: 2.5 kW, Solar World (10 units of mono-Si- SW 250)	Hoppecke 12 OPzS 1500, 1500 Ah, 2V Require 6 Battery in series and 1 string
Cost : 3 USD/ Wp	Cost : 735 USD/ Battery, Replacement Cost : 600 USD/ Battery
Life Time : 20 Years	Life Time : 10 Years
Pump and Motor Set: 600 USD	
Installing and Commissioning Cost: 300 USD	
Operation & Maintenance Cost/ year: 50 USD	
Interest rate: 1.5%	

Table 5: Cost type of PV-Battery System



This is proper sizing for this project as there have almost no unmet load. Monthly electricity Production, dump energy and unmet load of this system as shown in Table 6 & Fig 2.

Table 6: Annual Electricity production and consumption Demand

Production	kWh/yr.
PV array	3,897
DC primary load	2,152
Excess electricity	1,704
Unmet electric load	1.3

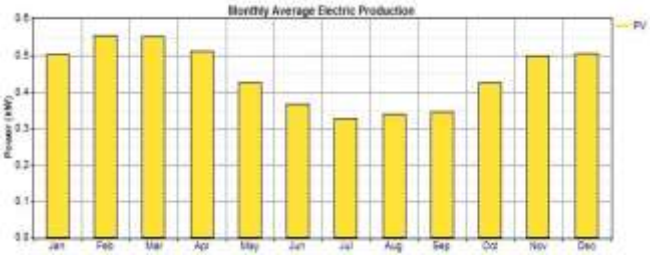


Fig. 2: Monthly Average Electric Production

Fig. 2 describes the monthly average electric production in Bangladesh. Financial studied is carried out with the help of HOMER and RETScreen simulation software. Simulated results are almost same as mentioned in the bellow Table 7.