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An Efficient and Feasible Solar Irrigation System Including AC Mini-Grid Designed for Bangladeshi Agriculture

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Abstract— The idea of introducing a mini-grid along with irrigation is originated considering the huge load shedding of a particular area. People of that area remain without electricity for approximately 6-8 hours in a day. A small survey was also conducted on 50 houses of Teghoria, Poradaho, Mirpur, Kushtia, Bangladesh and data were collected about their electricity demand during the time of load shedding every day. The mini-grid would be powered by the extra energy coming from the irrigation panel. This was done simply by changing the run time of the motor in an efficient way. The run time of the motor varies in different seasons. HOMER software was used to calculate the cost analysis of the proposed model for irrigation along with ac mini-grid. The proposed model provides two welfares. The first one is that the rural farmers can get water for irrigation with a lower installment which is shown in the paper. The second one is that the demand of electricity of rural people during load shedding can also be fulfilled from the ac mini-grid. Therefore, the overall cost can be minimized and the new irrigation system becomes more feasible for rural farmers as well as for the owners.

Index Terms— Feasible Solar Irrigation; Mini-grid; Surplus Energy; Cost Analysis; HOMER

1 Introduction

Solar Irrigation System is very much ideal in a remote rural area where electricity is another name of uncertainty in Bangladesh. Solar pumps are powered by photovoltaic (PV) panels and the rate of power generation depends mainly on solar irradiation in that particular area [1]. In recent times Bangladesh is progressing towards industrialization very fast, but still a major number of people in Bangladesh rely on its agriculture. Crop cultivation depends mainly on proper irrigation and since Bangladesh has been affected by the climate change like other parts of the world, irrigation became dependent on ground water pumping [2]. For irrigation, solar irrigation system is gaining popularity in recent times since there is no need to buy fuel for the pump, panels have no moving parts and most of the commercially available panels have a warranty of at least 20 years [3].

The existing Solar Irrigation System consists of an electrical pump system in which the power is provided by one or several PV panels. In this system the PV array simply powers an electric motor which powers a surface pump and the water is then pumped out from the ground into the field [4]. In this system some extra wireless control modules have been integrated in some projects so that the farmers can water the field from any location to water the field [5]. But what this system lacks is proper utilization of generated power by the PV panels since the generated power is dedicated only for running the pump. When irrigation is not needed, the system is kept idle. In a country like Bangladesh where most of the rural areas suffer from load shedding due to insufficient electricity supply, the current Solar Irrigation System can be modified to aid the dire need of electricity for the rural households.

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2 Proposed solar irigation model

After observing the present scenario of solar irrigation in Bangladesh including prospects, challenges and constraints, a viable solution has been proposed to make the solar irrigation more sustainable in Bangladesh. Here all the aspects of grid networks and solar irrigation in Khustia, Bangladesh have been considered. The main system will be divided into two parts.

1. Solar irrigation for cultivation.
2. AC mini grid for rural people.

Since the first priority is solar irrigation, so the system is designed considering the water pump as the primary load. It was found from the analysis that farmers do not need water for irrigation every day in a month and battery is not required to run the water pump. Therefore, the motor is not needed every day. A good amount of extra/unused electricity can be produced when the motor is off. Finally, an AC mini grid was introduced using this extra energy for the domestic load of the rural people. A survey was conducted on the load demand for summer and winter season in that particular rural area. In the proposed de-

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sign ACSR – Tharasher aluminum conductor is used. Specification of the Tharasher is given below:

- Diameter : 0.045771 m
- R at 27C : 0.0266 ohm/km
- Ampacity : 1000A

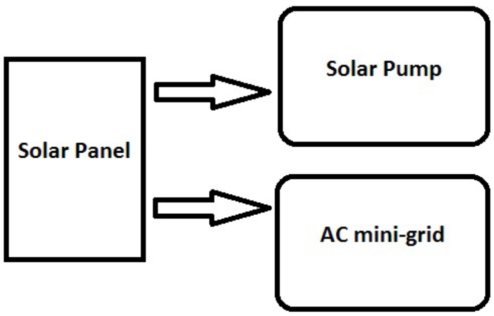

Fig. 1. Incorporation of ac mini-grid with the existing system

2.1 Irrigation Scenario in Winter Season

During winter season the land becomes so dry that farmers need to water the land whole day. Alongside the rural people also need electricity for the households. But the farmers also assured that they do not need water every day in winter season for irrigation.

Therefore, the motor can be run in one day interval during the winter season. Energy generated during this interval can be stored in the battery for serving domestic load.

2.2 Irrigation Scenario in Summer Season

During summer season the motor needs to be turned-on for 4 to 5 hours every day. Due to rainfall and soil fertility, water requirements for summer are less than the winter season.

After that particular 4-5 hours motor running, the solar radiation is used to charge the batteries meeting the electricity demand for the households.

2.3 Calculation for Solar Irrigation

The following is the load calculation for winter season in the village Teghoria of district Kushtia, Bangladesh [6, 7].

Load (Motor)- Size – 13 KW (From the visited project)

Assume,

Working hour per day - 8 hours (9.00am – 5.00pm)

Energy Required - (13*8) = 104 kWh per day

PV sizing:

Assume, the average peak sun hour = 4.2

$$\frac{Daily\ Energy * derating\ factor}{Avg\ peak\ sun\ hour * Wire\ loss * inverter\ eff}$$

PV Capacity $= 36.848\ kWp$

Inverter sizing:

Total load$= 13 * 1.25 = 16.25\ kw$; (Assume, efficiency 80%

2.4 Calculation for AC Mini-Grid System

The following is the load calculation for summer season in the village Teghoria of district Kushtia, Bangladesh [8].

Assuming,

Light = 10W

Fan = 20W

TV = 40W

A survey was conducted on 50 houses of that remote area,

From the field survey, data shows that

For the Summer season, Total domestic load demand
$= 25.4\ kwh\ per\ day$

Battery sizing:

Assume, Total domestic load
$= 40\ kwh\ per\ day$

This is more than total domestic load demand to ensure availability of electricity in that area.

Total Ampere hour per day ,

$$= \frac{Daily\ Energy}{System\ Nominal\ voltage}$$

$$= \frac{40\ kwh}{48\ v}$$

ISSN 2229-5518

$= 833.33\ Amp\ hour\ per\ day$

Assuming nominal voltage = 48 V; for this design

Corrected load,

$$= \frac{833.33\ Amp\ hr\ per\ day}{Battery\ loss*Charge\ cotroller\ loss*inverter\ eff*wiring\ loss}$$

$$= \frac{833.33}{0.9*0.98*0.96*.98}$$

$= 1004.27\ Amp - hr\ per\ day$

Size of Battery,

$$= \frac{Amp-hr}{Day} * \frac{Days\ of\ Autonomy}{Depth\ of\ Discharge}$$

$$= \frac{1004.27}{Day} * \frac{2}{0.6}$$

$= 3347.57\ Amp\ hour\ (Ah)$

Battery in parallel

$$= \frac{3429.35\ Ah}{200\ Ah}$$

(Assuming, Each Battery size- 12V, 200AH)

$= 17\ Batteries$

Battery in Series

$$= \frac{System\ nominal\ voltage}{Battery\ voltage}$$

$$= \frac{48}{12}$$

$= 4\ Batteries$

Total number of batteries

$= (17*4)\ Batteries$

$= 68\ Batteries$

From the survey on 50 houses,

Total domestic load demand for winter season was found $= 8.34\ kwh\ per\ day$

Batteries required for summer season $= 68\ batteries$

when the load is 25.4 kWh in summer seaon.

Therefore, 68 batteries are also sufficient for winter season because the load is only 8.34 kWh in winter season.

3 Cost Analysis

Cost analysis of the proposed Irrigation model was done by HOMER. HOMER is a computer model that simplifies the task of designing distributed generation (DG) systems - both on and off grid. HOMER's optimization and sensitivity analysis alg ... ic and technical fea ... c- cou ... e ava ... g poi

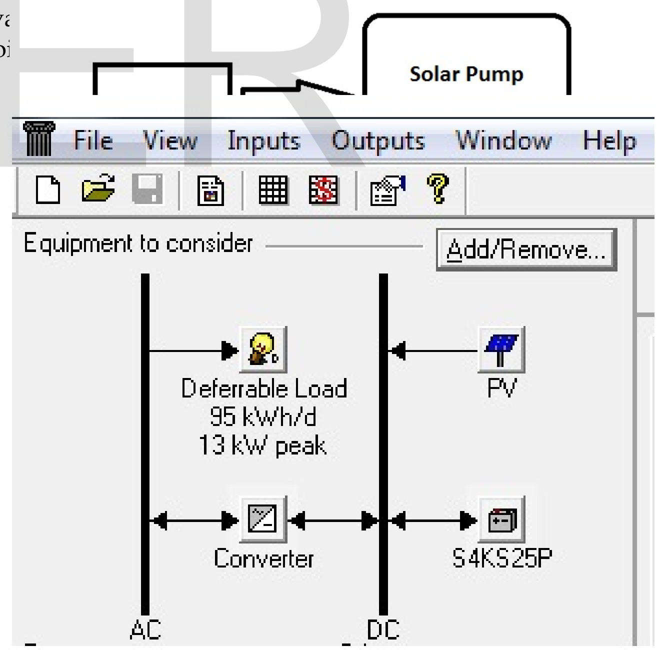

Fig. 2. Necessary equipment consideration

Deferrable Load

Deferrable load is the electrical load that must be met within some time period, but the exact timing is not important. Loads are normally classified as deferrable because they have some storage associated with them. Water pumping is a common example - there is some flexibility as to when the pump actually operates, provided the water tank does not run dry.

Other examples include ice making and battery charging.

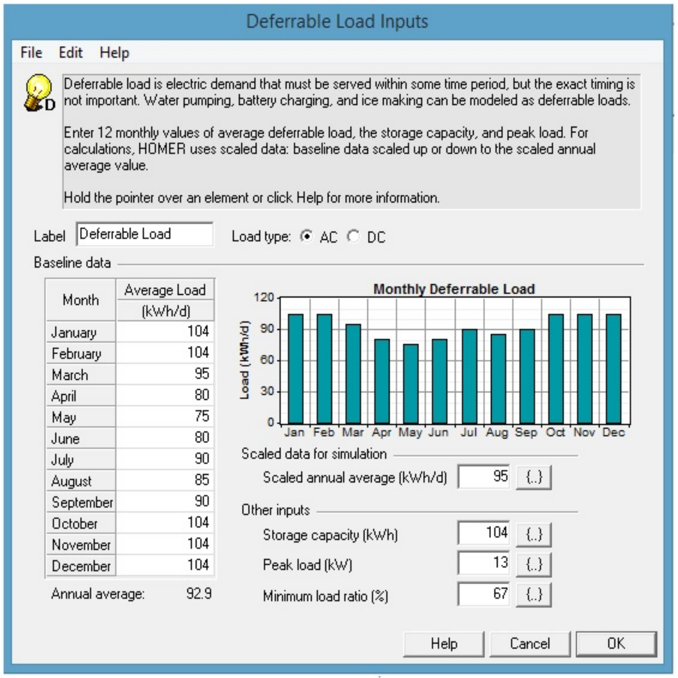

Fig. 3. Deferrable load inputs

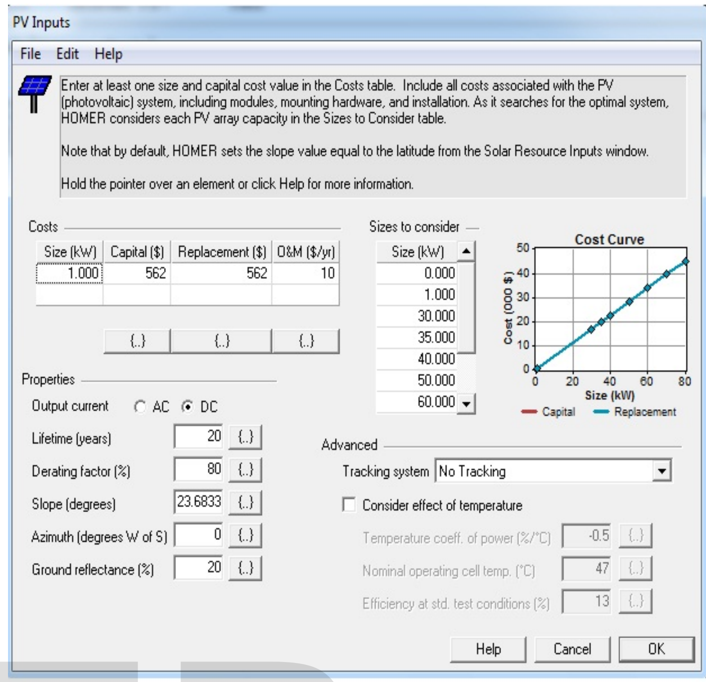

Fig. 4. PV inputs in HOMER

PV Inputs

PV input is to provide the PV information for instance capital, replacement, operation & maintenance cost and also the sizes of PV etc. When specifying the capital and replacement costs, it is necessary to account for all costs associated with the PV subsystem, which includes.

- PV panels
- mounting hardware
- tracking system
- control system (maximum power point tracker)
- wiring
- installation

Solar Resource Input

Solar Resource Input is used to give input the daily solar radiation data. Homer uses solar resource inputs to calculate PV array power for each hour of the year.

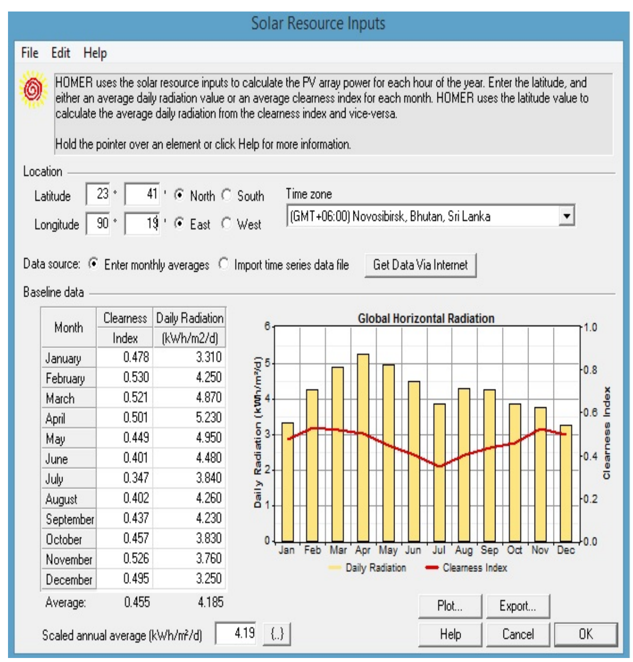

Fig. 5. Solar resource inputs in HOMER

HOMER Output

Cost of Energy (COE) is one of the most important parameters to determine the cost to produce 1kwh energy based on the given design. This is the average cost per kWh of electricity. The COE is a convenient metric to compare different systems in HOMER. The **COE** of our proposed design is **0.203 US dollars** which is equivalent to **16.24 BDT.** That means that the cost of energy is **16.24 taka/kWh.**

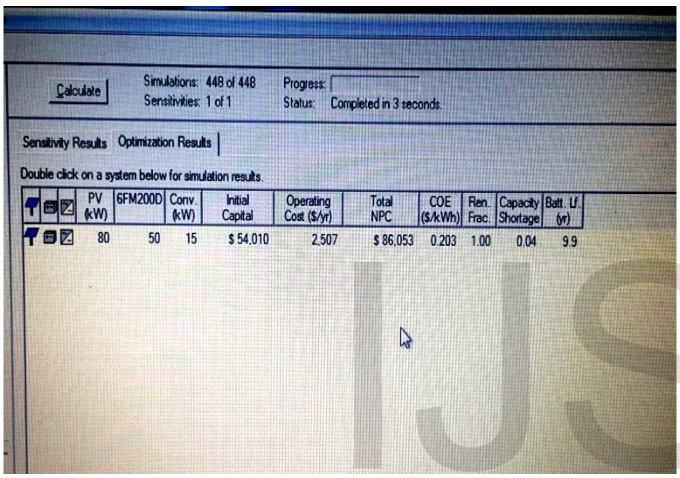

Fig. 6. Cost of Energy (COE) based on proposed design

System Outcome and discussion

According to the information provided by Bright Green Energy Foundation (BGEF), practical field analysis and simulation using HOMER software, the following cost analysis has been generated where energy cost of the Irrigation system including and excluding mini-grid has been shown.

Issues	Diesel pump		Solar pump (Without ac mini grid)	Solar pump (With ac mini grid)
Land area	1 bigha		1 bigha	1 bigha
Irrigation	1 time		1 time	1 time
Cost **1 bigha and 1 irrigation**	Engine rent 200 tk	Diesel price 70 tk/lit *2	3 months, total 50 times irrigation cost = 3500 tk 3500/50=70	3 months, total 50 times irrigation cost = 2368 tk 2368/50=47.72
	Total=340 tk		**Only 70 tk**	**Only 47.72 tk**
Cost per season per bigha (Boro)	25 irrigations (200*25)+(50*70) = 8500tk		50 irrigations Only 3500tk, Cost of Energy (COE) 24 tk per kWh	50 irrigations Only 2368tk, Cost of Energy (COE) 16.24 tk per kWh
Energy Surplus	No Extra Energy		Extra Energy but no Use	Supply Extra energy to the ac mini grid (50 houses)
Labor	1		None	1
Quality of crop	Good		Better	Better
Availability of water	Not available		Available	Available

Table 1. Overall system output comparison

The table illustrates different features of 3 different irrigations model focusing on the irrigation cost and surplus energy for Kushtia district.

Overall, all the three systems used the same area and same time duration for irrigation but the proposed design gives the most efficient yield in terms of COE as well as surplus energy. The solar pump with ac mini grid costs only 2368 tk per bigha for irrigation whereas solar pump without ac mini grid costs 3500 tk per bigha and the Diesel pump cost the most which is 8500 tk for per bigha irrigation. On the other hand, solar pumps produce surplus energy that the diesel pump couldn't. But only the pump with ac mini grid makes the proper use of this surplus energy by supplying electricity to 50 houses during the load shedding time on that area. This makes our proposed irrigation system most productive as well as cost effective. This system also ensures a comfortable life style of the rural people of that area who suffer from load shedding 8-9 hours in a day.

Henceforth, quality irrigation at relatively low cost, and relaxed mode of life, can be provided by the anticipated design. This may increase the working hour of the rural people of that area which could facilitate to improve the rural economy.

4 Conclusion

A small survey was conducted on 50 houses of Teghoria village, Kushtia, Bangladesh about their electricity demand during load shedding. Considering different aspects of that project and attitude of the farmers and owners, a new model of irrigation has been proposed in this paper. According to the proposed new model, some extra energy is stored in the minigrid and it is served to the rural people during the time of load shedding. In this way, rural people will get electricity as per their demand. On other hand, the overall cost of the irrigation system has also been minimized found from the HOMER software. It was found from the practical visit that though the cost of solar based irrigation is less than the diesel based irrigation, owners of the project and farmers are not happy with solar irrigation for different reasons. In the new proposed model, both parties will become more interested about solar irrigation as the installment cost for the crops decreases at a good rate. Rural people will become more efficient as they will get electricity during load shedding. It may also change the life style of the rural people which will further develop their socioeconomic status.

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