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EFFECTIVE PUMPING SYSTEM USING PVSYST TO HARNESS SOLAR POWER FOR BANGLADESH AGRICULTURE SECTOR

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Abstract— **For agriculture work, irrigation is a necessity. The tropic of cancer line goes through Bangladesh causing high temperatures in summer with high UV sun rays. Due to global warming, neighboring India's Farakka barrage over Ganges-Padma stream and other issues, scarcity of water for irrigation is severe in rural areas. Agriculture being the economic backbone, government is investing in water resource development aimed at large-scale irrigation development for increasing agriculture productivity. This paper proposes a design and simulation using "PVsyst" software for a solar powered pumping system for rural regions. Electrical power used for this simulation was 350 Wp and head was 25-35 meter. The subsystem would use DC motor and a closed loop control system has been incorporated for the control purpose. Then the daily performance was measured and compared with the simulated performance.**

Keywords— **Solar power generation, Pumps, Irrigation, Power system simulation, Agricultural engineering.**

I. INTRODUCTION

The use of water for agricultural production in water scarcity regions requires innovative and sustainable research, and an appropriate transfer of technologies [1]. The Earth's renewable fresh water resources are finite. Given world population growth, fresh water availability for 2050 is estimated to be 4380m3 per person per year. While this result suggests no foreseeable shortage in per capita availability, fresh water is distributed unevenly in space and time. Indeed, by 2025 as many as 3 billion people may be living in ''water-stressed'' countries (Seckler, Amarasinghe, Molden, de Silva, & Barker, 1998; Postel, 1999). And by 2050 nearly 1 billion people living in the Middle East and North Africa will have <650m3 of water per persons, a severe water shortage by any standard.2 Irrigated agriculture now occupies 18% of the total arable land in the world and produces more than 33% of its total agricultural production. However, the likelihood of additional irrigation projects sufficient to meet increasing food demands is questionable, given mounting concerns over the adverse effects of large dam projects, and losses of land to salinization (Sampath, 1992; Rosegrant & Meinzen-Dick, 1996; Postel, 1999).

More likely is the modernization of existing irrigation systems to enhance efficiency and to cater to the new institutional structures, technology, and food demands (Bandaragoda, 1998). Seckler et al. (1998) estimate that improvements in irrigation efficiency alone may meet one-half of the increase in water demand through 2025. Because water in general and irrigation water in particular often require initially large capital investments in infrastructure development, governments are often required to allocate water resources [2]. But we are working on to minimize the initial large capital investments. The irrigation system comprises the PV array and pumping components such as DC motor, positive displacement pump and a control system. The intention for this research work is that Bangladesh is currently suffering from acute power crisis. Natural gas is the main energy source of Bangladesh and the power generation sector is heavily dependent on that. In 2014, 8,340 MW were generated using 337.4 BCF natural gas. According to the Power System Master Plan 2016, the gas production from the domestic gas field will reach its peak in 2017. T. The urban population here are not getting the proper supply of gas for the cooking purpose. On the other hand, the price of the fossil fuel increasing rapidly. Due to these two problems the farmers in the rural areas are not able to irrigate the crops field properly. As the conventional swallow machine use the fossil fuel or electricity. So, considering all these circumstances we have developed a cost-effective pumping system to harness the solar energy. The current energy sector scenario of Bangladesh, total mechanism of the system is described in the following sections.

II. ETHODOLOGY M

For the following paper, various PVsyst internal database and meteo data were utilized. The derived mathematical model was used to simulate the actual system. Using the various data and interchanging the values, the system was tested for real life feasibility and the output results were further mentioned in the following paper.

III. SUMMARY OF PVSYST SOFTWARE

Photovoltaic Systems (PVSyst) PVSyst is a PV-centric simulation tool that was originally developed at the University of Geneva but is now a standalone company. The software package focuses on modelling, sizing, simulating and analyzing PV systems. PVSyst does have some sort of financial modelling in place, but it is primarily a performance modelling software. A typical simulation in PVSyst consists of the following steps:

1. Defining the project. This is where the user creates the desired project on the user interface, names it and selects the corresponding geographic location and meteo file to be used. A number of sites and meteo files are already included in the PVSyst databases but the user also has the option of importing his own. PVSyst supports several types of weather files such as TMY2, TMY3 and EPW and files from sources such as Meteonorm, Photovoltaic Geographical Information System (PVGIS), World Radiation Data Centre (WRDC), Retscreen, Helioclim and SolarGIS.

2. Creating a system variant. This is where the user creates a calculation version of the project created in step 1. On the interface, the user gets to define various input parameters such as module orientation, system configuration and loss parameters.

3. Running the simulation. The user runs the simulation and generates a variety of graphs and reports for the analysis of the PV system. PVSyst allows the user to analyze the results in the program, export them to a different program or save the variant for further evaluation.

PVSyst offers the users extensive reports and breakdowns and valuable insights into the engineering aspects of design and deployment. This allows PVSyst to cater for a wide range of users including researchers and architects. Its interface is also multilingual and available in other languages such as German, French, Spanish and Italian, in addition to English.

IV. ANGLADESHBECTOR INSOWERP

The per capita energy consumption in Bangladesh is one of the lowest (311 kWh in 2014) in the world [3]. To improve the situation, the Government has adopted a comprehensive energy development strategy to explore supply-side options along with demand management that conserves energy and discourages inefficient use

At present the total power generation capacity of Bangladesh is in August 2016 it was 12780 MW including the 600 MW power import from India. It is to be noted that capacity has grown rapidly over the last few years. Favourable Government policies have attracted private investment and Independent Power Producers (IPP). Out of the total capacity 46% are produced by the private producers [3]. So there is demand for electricity outstrips supply by around 2,000 megawatts at peak hours. In public sector, a good number of generation units have become very old & they are operating at a low capacity. For the last few years, the actual demand could not be supplied because of the shortage of available generation capacity. And due to the shortage of gas supply some power plants are unable to produce power of their usual generation capability. The country's power generation is basically mono fuel based and about 90% of them are produced from natural gas. Other forms are lone Hydro Electric Plant at Kaptai, the lone coal-based plant at Barapukiria and several small furnace oil & diesel plants in the northern & southern region. Gas supply constraint has restricted power generation specifically in Chittagong region. We failed to effectively explore & exploit our sizeable gas & coal resources to extract maximum national benefit. Due to the power crisis industrial operation & its further growth is almost halted. It tends to stall economy, trade& commerce. This is putting depleting forest resources under severe stress with consequent adverse environmental impacts.

V. ONSUMPTIONCNRGYEUELFOSSILF

The Fossil fuel energy consumption (% of total) in Bangladesh was reported at 73.77 % in 2014, according to the World Bank [4]. Fossil fuel comprises coal, oil, petroleum, and natural gas products. This page includes a historical data chart, news and forecast for Fossil fuel energy consumption (% of total) in Bangladesh. Bangladesh is considered as a developing economy which has recorded GDP growth above 5% during the last few years. Microcredit has been a major driver of economic development in Bangladesh and although three fifths of Bangladeshis are employed in the agriculture sector, three quarters of exports revenues come from garment industry. The biggest obstacles to sustainable development in Bangladesh are overpopulation, poor infrastructure, corruption, political instability and a slow implementation of economic reforms [3]. The prices of all fuel oils are listed in the table-1.

Name of the Fossil Fuel	Price in BDT
Petrol	83
Octane	89
Diesel	65
Kerosene	
Furnace oil	60

Table 1: Fossil fuel price comparison

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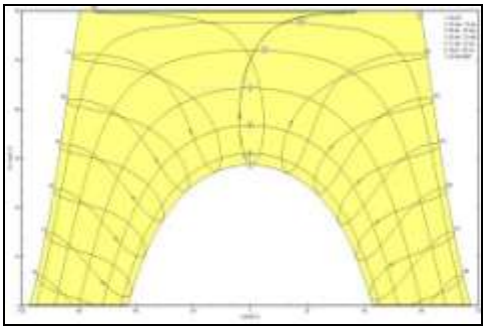
VI. BANGLADESH'S GEOGRAPHICAL POSITION

Bangladesh is situated between 20.30 and 26.38 degrees north latitude and 88.04 and 92.44 degrees east which is an ideal location for solar energy utilization [5]. This statement will be clearer after the demonstration of following Figs, table and graph. The sun paths in Bangladesh in rectangular coordinate and polar coordinate are depicted in the Fig 1(a) [6] and Fig 1(b) [6] respectively. The monthly representation of meteo values are listed in the table-2[6].



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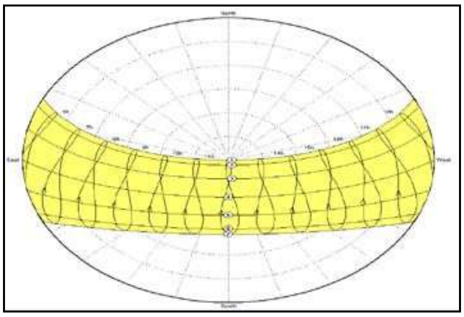

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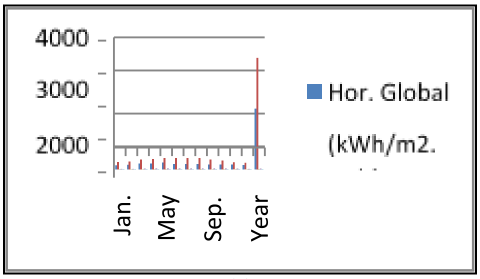
Fig. 1. The Figs show the sun paths in various positions: (a) Sun Paths in Rectangular Coordinate.; (b) Sun Paths in Polar Coordinate.

The source is meteonorm. Meteonorm monthly irradiance data are available for about 1'200 "stations", as averages of 1960- 1991 (and also 1981- 2000 in version 6.0). All "stations" (i.e. with irradiance measurements) of the main European countries are referenced in the PVSYST database. Data for any other site may be obtained by interpolation (usually between the 3 nearest "stations") [7]. Based on the table-2 the graph is depicted in the Fig-3. And from the Fig 2(b) to Fig 5 represents various graph that actually depict the geographical position of Bangladesh which in turn represent that our country is in a suitable position for utilizing solar energy.



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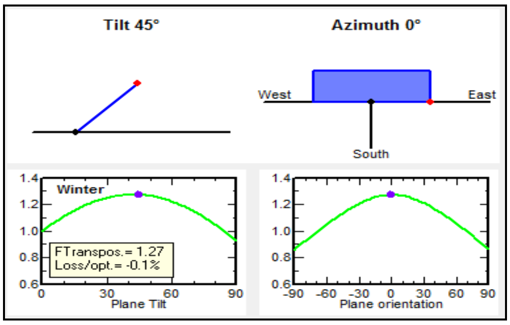

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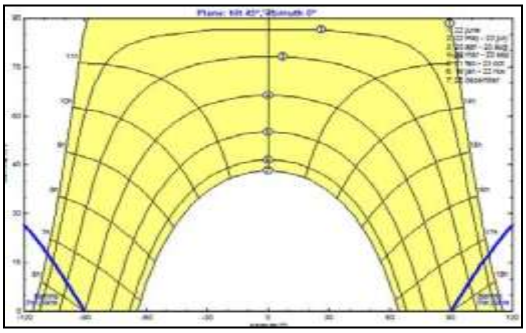
Fig. 2. The Fig shows the following graphs: (a) Meteonorm Graph; (b) Orientation Graph.

TABLE I. MONTHLY REPRESENTATION OF METEO VALUES.

Months	Hor. Global (kWh/m2.mth)	Extraterrestrial (kWh/m2.mth)	Clearness Index	Abm. Temper. Celcius	Wind Velocity
Jan.	128.6	216.7	0.594	19.4	1.5
Feb.	144.1	228.7	0.63	21.5	1.8
Mar.	175.4	291.6	0.601	26.2	2.1
Apr.	180.5	314.2	0.575	28.1	2.4
May	209.6	341.4	0.614	28.7	2.3
June	146.8	335	0.438	28.3	2.3
July	153.2	343.2	0.446	28.8	2.4
Aug.	148	330.8	0.447	28.7	2.1
Sep.	143.2	294.4	0.486	28.6	1.9
Oct.	141.9	266.3	0.533	27.6	1.7
Nov.	138.7	219.1	0.633	23.7	1.6
Dec.	133.5	205.3	0.65	20.4	1.4
Total	**1843.5**	**3386.7**	**0.544**	**25.8**	**1.9**



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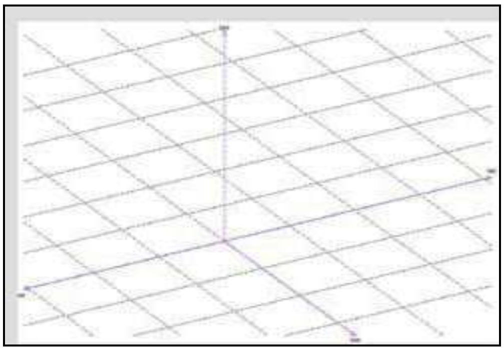

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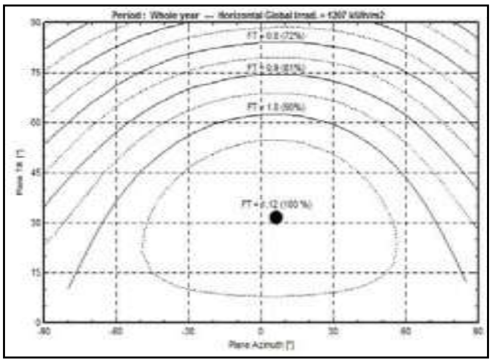
Fig. 3. The Fig show (a) Horizon line in Bangladesh; (b) Global Scene View.



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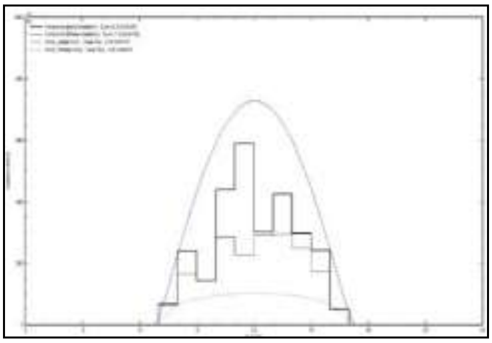

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Fig. 4. The Fig showing: (a) Transposition Factor for Bangladesh; (b) Meteo for Bangladesh.

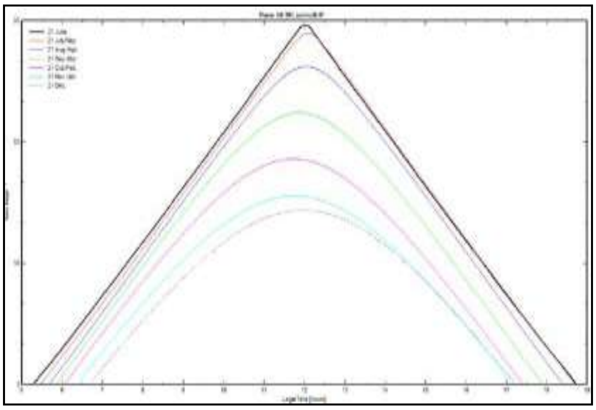


Fig. 5. The Figure shows the Sun Height at Bangladesh

1. Mathematical Model

The following mathematical equations are used for the simulation of the photovoltaic module. The solar current is denoted by the following equation.

$I = IL – I_0 [e\ A(V + R_sI) -1] –(V/R_{sh})$ ….(1)
$A= q/(A_kT_j)$ ….(2)
$IL = p_1\ E\ [1+p_2(E –E_{ref}) + p_3\ (T_jT_{ref}\ )]$ .... (3)
$I0= p_4T_{j3}\ exp(p_5/T_j)$ …. (4)
$P =A\ Q_3+BQ_2+CQ+D$ …. (5)

Here,
A = Coefficient of the exponential (Curve Fitting Constant).
I = Solar Current
V = Solar Voltage
Rs = Series Resistance
IL = Light- generated current
I_0 = Diode Saturation
q = Electric Charge
k = The Boltzmann's Constant
T_j = Junction Temperature
E = Solar Irradiance
E_{ref} = Reference Solar Irradiance (1000 W / m2)
T_{ref} = Reference Temperature (2980K)
I_c = Saturation Current
p_1, p_2, p_3, p_4 = Parameters
A, B, C, D = Parameters Determined from Calculation

A. Well characteristics

Static Depth	24 m
Max. Pumping Depth	26 m
Pump Depth	30 m

Borehole Diameter	18 cm
Spec Drawdown	1 m/m3/h

B. Storage Tank

Volume	20 m3
Diameter	3.50 m
Water full height	2.08 m
Feeding attitude	6.0 m

C. Hydraulic circuit

Pipe choice	PE20 (3/4”)
Piping length	60m
Number of elbow	2
Other friction losses	0.05

D. Water Needs

Water needs avg.	5 m3/day
Yearly water needs	1825 m3
Yearly head avg.	38 meterW
Hydraulic energy	189 kWh
PV needs (very roughly)	638 kWh

E. Pump(s) Model and layout

Sort pump by power	98W, 6-70 m
Nominal voltage	24V
Nominal current	7A

F. PV Array

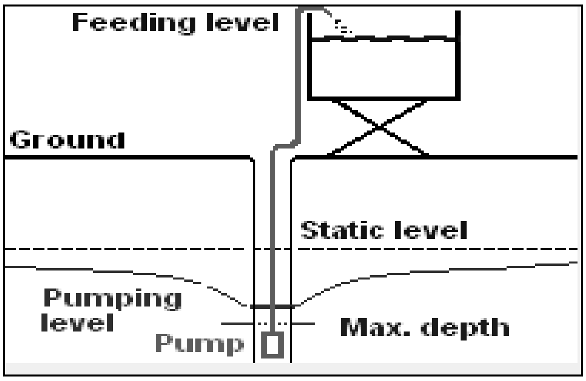
Sort model by power	60Wp, 24V
Array nominal power	240Wp
Array voltage (50°c)	29.7V
Array	7.1 A

G. PV Array summary

4 PV module of	60Wp
Array oper.	(50°c, 1000W/m2)
Pmpp	211W,
Vmpp	30V

H. Operating system

Direct coupling



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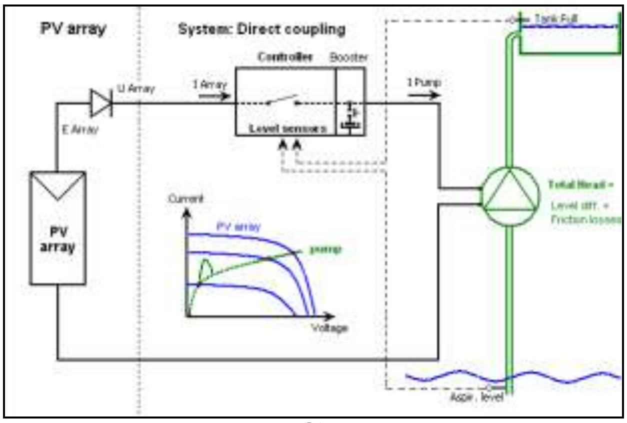

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Fig. 6. The Fig show the following architectural plans: (a) Flow Rate Function of Pumps Power; (b) Flow rate Function of Irradiance.

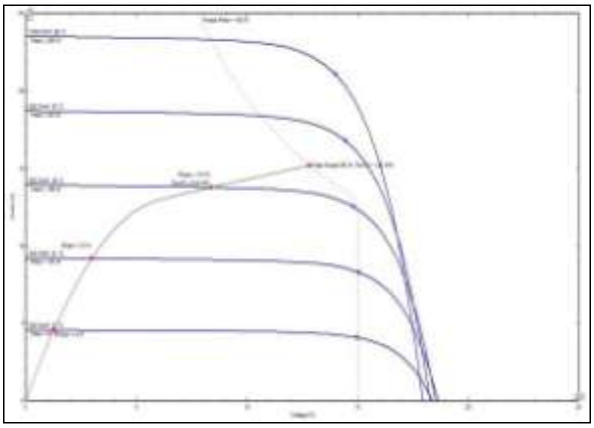
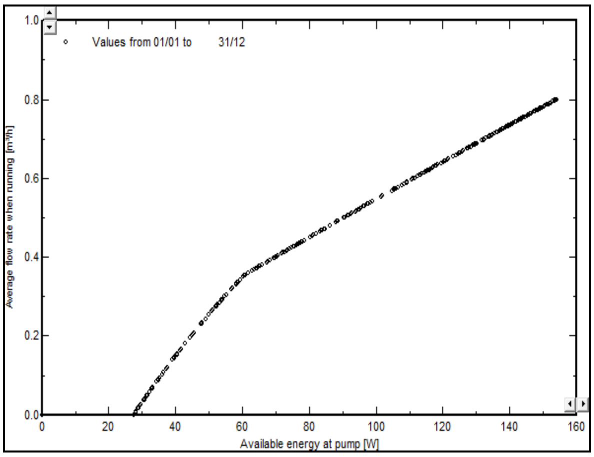


Fig. 7. A Graph representation for PV array and PV characteristics



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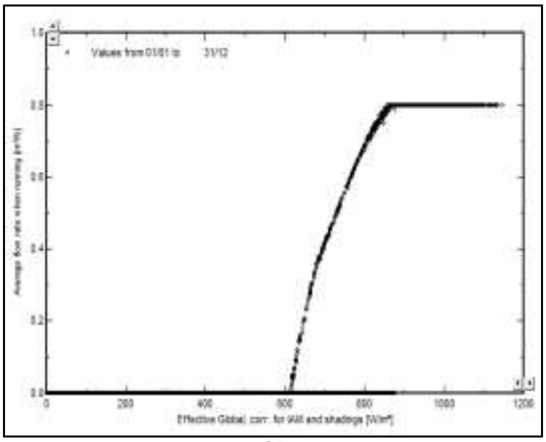

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Fig. 8. The Figs show the following architectural plans: (a) Flow Rate Function of Pumps Power; (b) Flow rate Function of Irradiance.

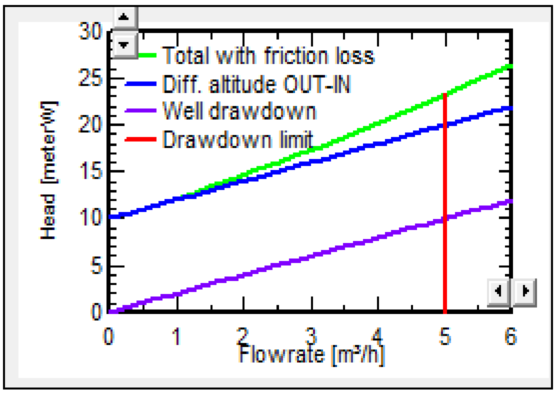

Fig. 9. The Fig shows the Output graph for the designated system

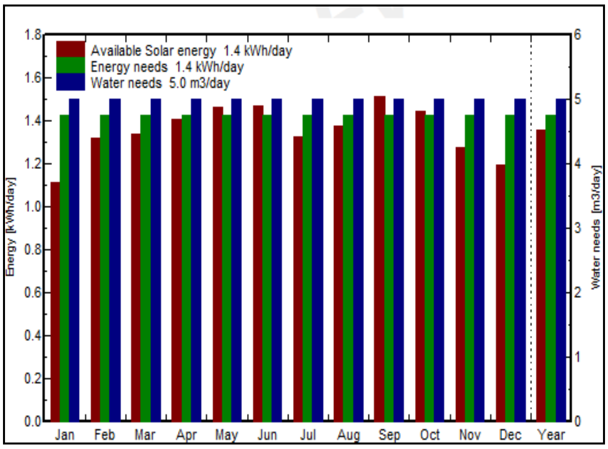

Fig. 10. PV.Needs Energy Yeild and Water

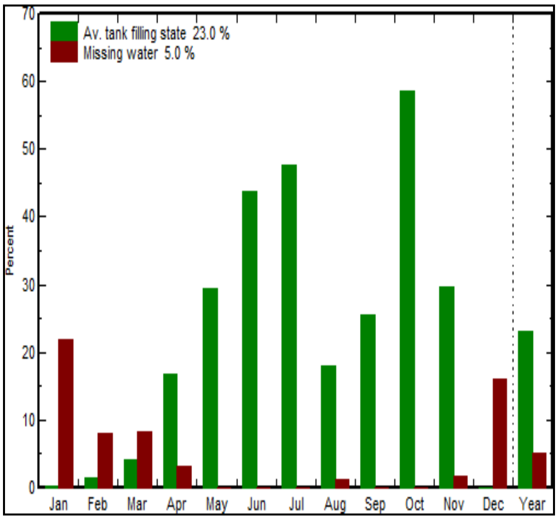

Fig. 11. Tank Level and Missing Water Probability.

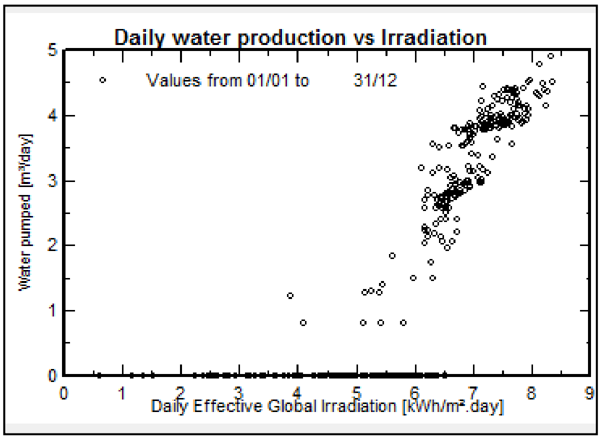

Fig. 12. Daily Water Production vs Irradiation.

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7.1 Pump characteristics

Pump: 1 pump
Type: deep well pump
Motor type: DC motor
Nominal operating condition:
Pressure =32.0 meterW
Flow rate=1.6m3/h

7.2 Array losses

i. Thermal parameter

Field thermal loss factor, U=Uc+UV=Wind vel.
Constant loss factor, Uc=29W/m2k
Wind loss factor, Uv=0.0 W/m2k/m/s

ii. Standard noct factor

NOCT coefficient 45°C.

iii. Ohmic losses

DC circuit: Ohmic losses for the array
Global writing resistance = 69.1 m ohm
Loss friction = 11.5%
Voltage drop across series diode = 0.7V

7.3 Module quality-mismatch

i. Module quality

Module efficiency loss = 3%

ii. Mismatch losses

Power loss at MPP 2.0%
Loss when running at fixed voltage 4%

2. System Design

In the design we actually used the "Deep Well" type configuration. A submersible pump is placed in the bottom of a borehole [7]. The diameter of the borehole that we select in the design is 12 cm. The water is pumped into the tank when the sun is available. The head is difference between the input and output level. For the calculation of the head we have used the following equation.

$$HT = HG + HS + HD + HF$$

Here,

HT = Total Head
HG = Head due to the height of the outlet pipe above ground
HS = Static Head
HD = Dynamic Head
HF = Friction Losses

a) Storage Tank

We have included a storage tank in the design as the solar yield is not constant. The storage tank is built on above the ground in such a way that the static pressure is sufficient for distributing the water by gravity. We have defined all the parameter in the software properly, i.e. storage volume, tank diameter, water height, alimentation mode. The total defining parameter in the software will be depicted in the later portion of the paper.

b) Piping Circuit

The main deficiency of the piping circuit is that it produces friction head losses. In time of designing the system in the software we have mentioned the pipe type, piping length and friction loss factor. The friction loss factor is 0.35.

c) Pump Motor Technology

In the design we have used the Brushless DC motor which seems to have higher efficiency. The main advantage while designing with this PVSYST software is that we have to specify on the motor type (DC or AC).

d) Hydraulic Power and Energy

The mechanical power of a Hydraulic flow is basically the product of the fluid flow rate, by the head at which it is transferred.

P hydr [W]= FlowR [m^3/h] * Head [Bar] * 1000/36
P hydr [kW] = FlowR [m^3/h] * Head [Bar] * 1/36

In the same way, the energy is related to the total water volume transferred.

E hydr [kWh] = Flow [m^3] * Head [Bar] * 1/36
E hydr [MJ] = Flow [m^3] * Head [Bar] * 1/10

e) Direct Coupling

The main reason for the use of DC coupling here is that we have used the DC motor pumps. The detailed schematic diagram is depicted in the Fig 6(a).

f) Array Losses in PVSyst

Array losses can be defined as all events which penalize the available array output energy by respect to the PV-module nominal power. Usually an array has the following losses.

- Thermal Losses
- Incidence angle modifier (IAM)
- Irradiance Loss:
- Ohmic Losses
- Module-Quality Mismatch
- Soiling Loss

i. Thermal Losses

The thermal behaviour of the array is computed at each simulation step, by a thermal balance. This establishes the instantaneous operating temperature, to be used by the PV modules modelling.
The thermal balance involves the "Heat loss factor"

$$U = Uc + Uv \cdot \text{Wind Speed } [W/m^2 \cdot K]\ [7].$$

ii. Wiring Losses.

The wiring ohmic resistance induces losses ($R \cdot I^2$) between the power available from the modules and that at the terminals of the array. These losses can be characterized by just one parameter R defined for the global array [7].

iii. Module Quality Loss

The aim of this parameter is to reflect the confidence that the designer put in the matching of your real module set performance, by respect to the manufacturer's specification [7]

iv. Mismatch Loss

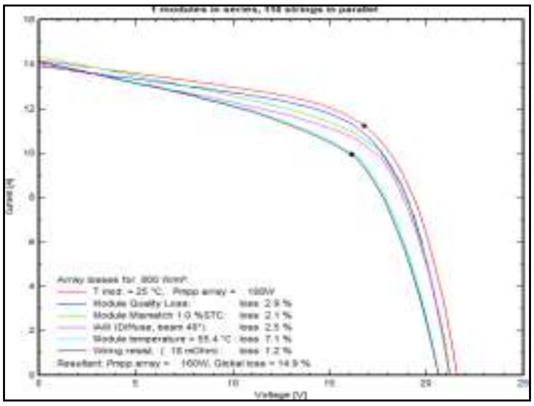
Losses due to "mismatch" are related to the fact that the real modules in the array do not rigorously present the same I/V characteristics [8].

v. Soiling Loss

The soiling effect is about negligible in middle- climate residential situations. It may become significant is some industrial environments (for example near railway lines), or in desert climates.

vi. IAM Loss

The incidence loss (reflections due to the Fresnel's laws) is sufficiently well defined by parameterization proposes by the "Ashrae" (US standards office) [7].



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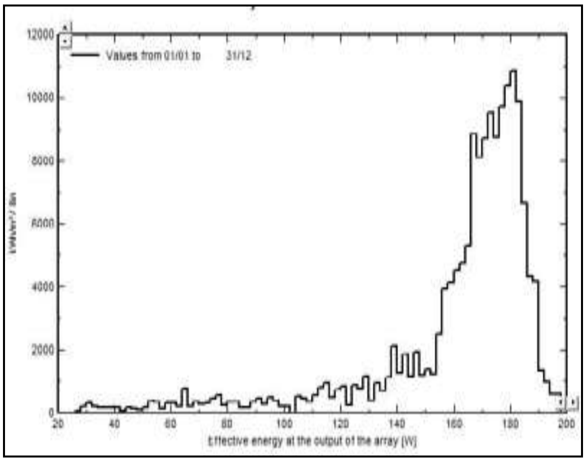

(b)

Fig. 13. The Figs show the following architectural plans: (a) Array losses; (b) Array Power Distribution.

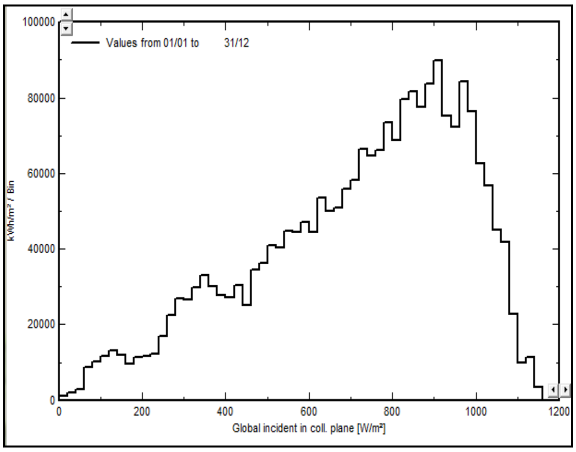

Fig. 14. Incident Irradiation Distribution.

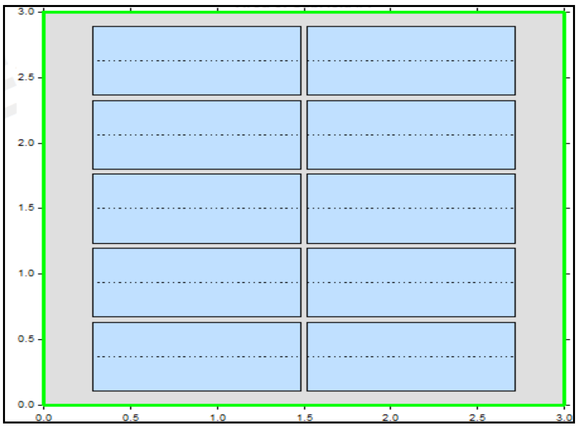

Fig. 15. Module Layout.

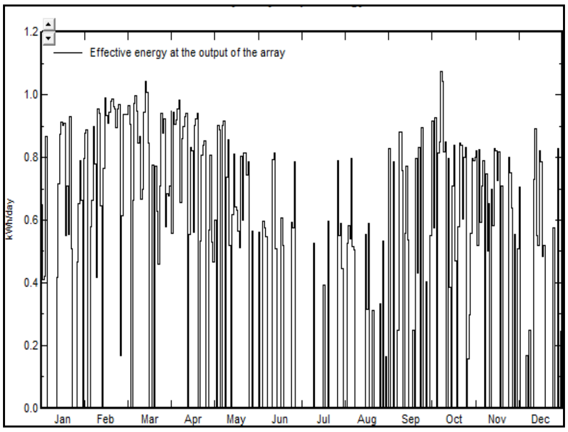

Fig. 16. Daily Array Output Energy.

IV.CONCLUSION

We have designed and analyzed our system by using the PVSYST software. The graphs that are depicted in this paper represent the simulation result while designing the system [7]. And for every step in our simulation we almost got the results which are very nearer to the ideal one. Through our previous works in similar project about satellite-based imaging [9] and especially the solar powered pumping system [10], we got interested to delve deeper into the topic. This study shows that this kind of solar energy utilizing pumping system is very useful for the agriculture and especially for the remote areas in the desert. Our total estimated cost for the fabrication of this kind of irrigation system is 175 USD which is equal to the 14000 BDT. The main problems with this kind of system are the high cost of the solar panel. If we could decrease the price of solar panel then only it will possible for us to decrease the implementation cost for the proposed system. The use of this kind of system could have an important contribution in the social and economic development of a country.

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