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Evaluation of Solar-Powered Water Pump for a Remote Health Facility in Akwa Ibom State

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***Abstract*— In this paper, evaluation of a solar-powered water pump for a remote health facility in Akwa Ibom state was carried out. The evaluation was conducted using state of the PVSyst software that has the requisite tools and features for studying solar systems and solar powered facilities. The case study health facility is located in Ibsipko in Akwa Ibom state with longitude and latitude of 7.928791 and 4.977536 respectively. The water demand survey was conducted for the case study health facility and the daily water requirement of $28\,\mathrm{m}^3/\mathrm{day}$ with 4 days storage capacity of $112\,\mathrm{m}^3$ was established. The meteorological data for the case study site was gotten from the NASA website and the simulation was conducted using PVSyst software. The results showed that in a year, about 10154 m^3 of water is pumped while about 10220 m^3 of water is needed which gave a yearly missing water of 0.6 % . Also, the results showed that the pumping system has an overall system efficiency of 65.9% , system performance ratio of 0.53 and specific energy yield of 1.62kWh/m^3. In all, the month of July had missing water of 6% which was slightly above the required annual upper threshold of 5%. In any case, the July missing water was not critical as the rainwater in the month of July can easily provide the shortfall in the water supply from the solar powered pump.**

***Keywords*— Solar Energy, Solar Powered Pump, Renewable Energy, Water Demand, Performance Ratio**

I. INTRODUCTION

In the developing countries, hospitals in the remote rural locations suffer in many ways; lack of adequate manpower [1,2,3,4,5,6,7], lack of adequate clean water [8,9,10,11,12] and poor electric power supply [13,14,15,16,17,18, 19]. The manpower problem is associated with lack of essential amenities in the rural areas; again, the difficulty in clean water supply along with poor power supply top the list of reasons why qualified manpower are avoiding the rural communities. Consequently, some health facility owners in the rural communities seek to address the problem by using alternative power supply to provide regular electricity and clean water for the health facilities.

In this paper, a solar photovoltaic water pump for a health facility is simulated and the simulation results are analyzed to ascertain that the water pump will meet the water demand of the health facility throughout the year. In this case, 5% yearly average missing water is set as the upper limit on the performance of the solar-powered water pumping system. It is expected that the rainwater is also harvested by the health facility and such water can help to compensate for any slight excess missing water during the rainy season months. The rest of the paper presents the system parameters, the simulation process and the discussion of the results.

II. THE CASE STUDY HEALTH FACILITY AND ITS METEOROLOGICAL DATA

The case study health facility is located in Ibsipko in Akwa Ibom state with longitude and latitude of 7.928791 and 4.977536 respectively. The monthly average daily global solar radiation on the horizontal plane and on the optimal tilt angle for the health facility are given in Table 1. PVSyst software [20,21] was used to select the winter months' fixed optimal tilt angle, as shown in Figure 1. The choice of the winter optimal tilt angle is because in the study area the winter months are the dry season months when there is very little rainfall. As such, the PV modules are installed at such an optimal tilt angle targeted at maximum solar radiation capture for the winter months.

Table 1 The monthly average of daily global solar radiation on the horizontal plane and on the optimal tilt angle for the health facility at Ibsipko Akwa Ibom State

Meteo File NG_MKPAT_ENIN_AKS_SYN.MET, Monthly accumulations

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Meteo for MKPAT_ENIN_AKS, Synthetic data

Plane: tilt 8°, azimuth 0°, Albedo 0.20

Interval beginning	GlobHor kWh/m².mth	GlobInc kWh/m².mth
January	161.2	171.0
February	146.7	152.2
March	148.8	150.0
April	138.0	135.8
May	131.1	126.5
June	106.2	102.0
July	100.4	96.9
August	106.0	103.5
September	102.9	102.7
October	114.1	116.2
November	126.3	131.6
December	153.5	163.3
Year	1535.2	1551.8

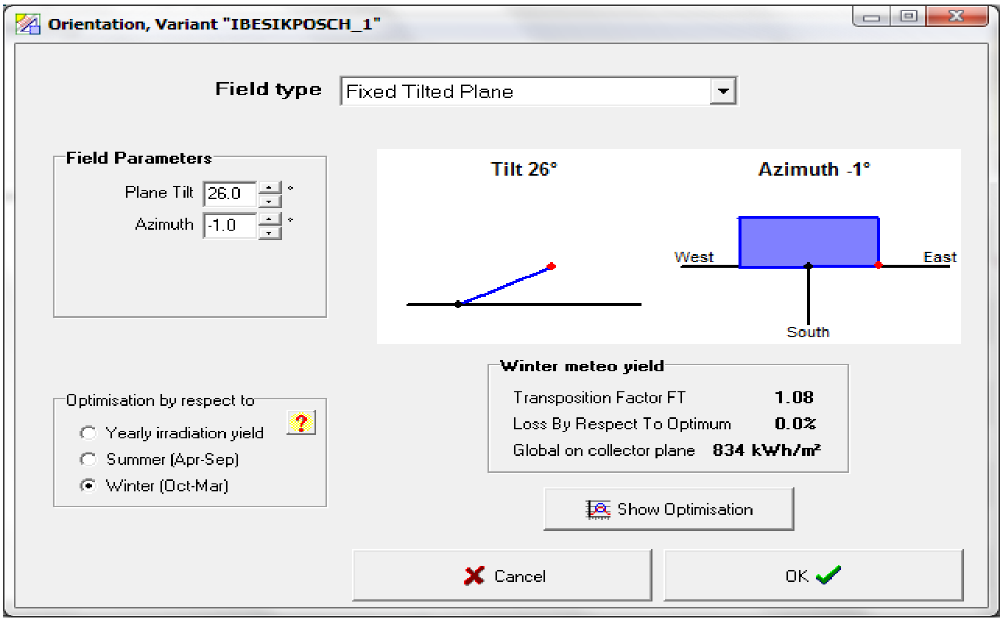

Figure 1 The winter months fixed optimal tilt angle for the PV modules

III. THE DAILY WATER DEMAND AND OTHER SYSTEM PARAMETERS

Apart from the solar resource, the daily water demand of the hospital is needed to select the appropriate water pump and PV module suitable for the hospital. The water demand survey of the hospital showed that the hospital has a capacity of 20 beds and a staff quarter that has an average of 5 resident staff. There is also about 8 day-workers. In addition, the hospital attends to an average of 80 outpatients every day. The daily water demand of the hospital is given in Table 2. Furthermore, one (1) USA gallon is equivalent to 0.00378541178 m^3, hence the daily water demand of the health facility is 7270 gallons/day or 27.5 $m^3/day \approx 28\ \mathrm{m}^3/\mathrm{day}$. The water source is a borehole and a deep well-to-storage approach is used. About four (4) days of autonomy is required, as such the storage tank capacity is 112 m^3 which is four times the daily water demand. The parameters of the storage tank, the well and the hydraulic circuit are given in Table 3. The parameter in Table 1, Table 2 and Table 3 are used in PVSyst software to select the pump and PV modules that will deliver the required daily water demand and three days storage capacity.

Table 2 The daily water demand for the health facility

Hospital water consumer category	Population	Water demand per day in gallons per day or gpd [19]	Total demand per day in gpd
Hospital beds	20	250	5000
Resident hospital workers	5	250	1250
Hospital day workers	8	15	120
Outpatients (per day)	60	15	900
Total			7270

Table 3: The parameters of the storage tank, well and hydraulic circuit

Storage Tank Parameters		The Well Parameters		The Hydraulic Circuit Parameters	
Volume	112 m^3	Static level depth	63 m	Pipes Type and diameter	PE20(3/4”)
Diameter	6.9 m	Max. pumping depth	70 m	Piping length	180 m
Height (full level)	3.0m	Pump depth	73 m	Number of elbows	10
Feeding altitude	16m	Well diameter	40 cm	Other friction losses	0.5
				Water needs (yearly constant)	$28\mathrm{m}^3/\mathrm{day}$

IV. RESULTS AND DISCUSSION

The PVSYST simulation main result screenshot for the hospital is shown in Figure 2 which shows that there is a missing water of 0.6 % is the entire year. In a year, about 10154 m^3 of water is pumped while about 10220 m^3 of water is needed in a year. This gives the missing water of $\left(\frac{(10220-10154)}{10220}\right)100\% = 0.64\,\%$). Furthermore, Figure 2 shows that the pumping system has an overall system efficiency of 65.9% and specific energy yield of 1.62kWh/m^3.

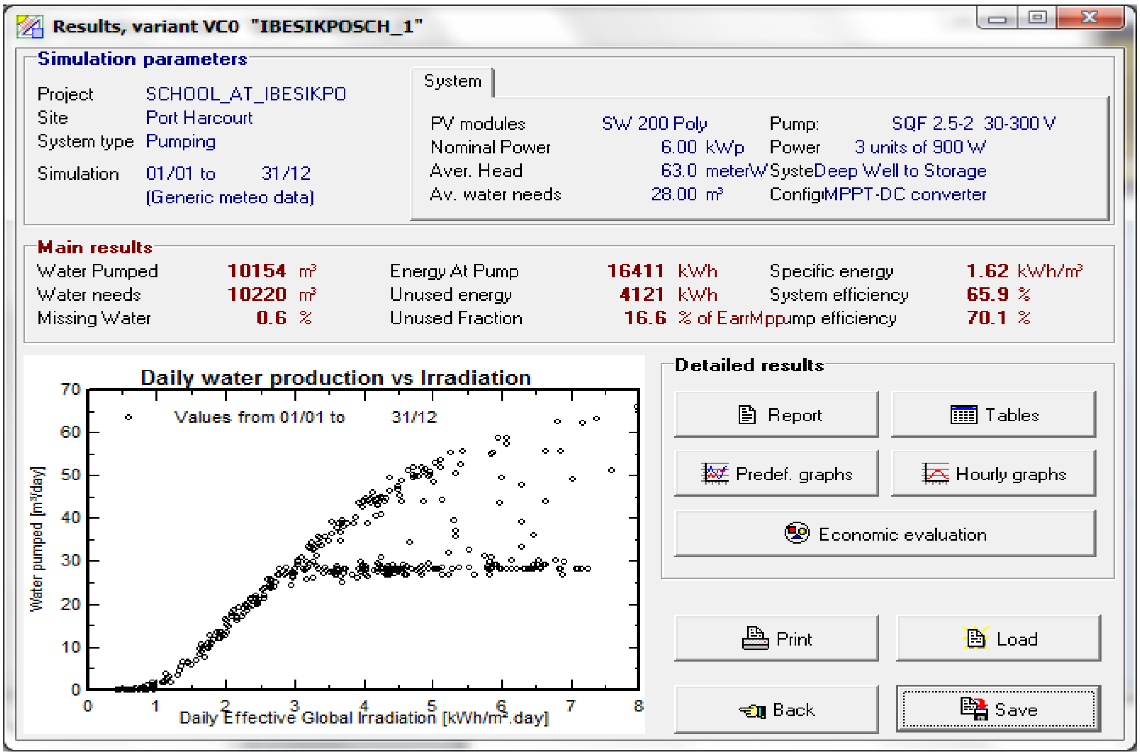

Figure 2 The screenshot of the PVSyst Main Result

The PVsyst balances and main result is given in Table 4 which shows that the highest missing water occurred in the month of July with a daily missing water of $1.690\,m^3$ which is about 6 % of the $28\,m^3$daily water demand; that is $\left(\frac{(1.69)100\%}{28} = 6\,\%\right)$. Given that the overall missing water is 0.6 % which is below the 5% maximum required in a year, the 6% missing water in the month of July can be allowed since July is among the period of heavy rain in the case study area. As such, the missing water will be supplied from the rainwater.

The normalized production and loss factor in Figure 3 shows that the system has an effective energy of 53% at the pump. This is equivalent to system performance ratio of 0.53. Figure 3 also shows that about 20.7% of the energy was wasted because at that point the water was not used (users need was already met) and the water was not stored (the storage tank was already full). In that case, the storage tank can be oversized to capture this wasted water which will eventually further reduce the missing water and also increase the system performance ratio. Also, reduction in the number of PV module coupled with monthly adjustment of the optimal tilt angle of the PV modules can also help to address the excessive loss in unused energy due to tank full condition.

Table 4 The PVsyst balances and main result

Simulation variant : IBESIKPOSCH_1

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IBESIKPOSCH_1

Balances and main results

	GlobEff kWh/m²	EArrMPP kWh	E PmpOp kWh	ETkFull kWh	H Pump meterW	WPumped m³/day	W Used m³/day	W Miss m³/day
January	137.9	683.2	400.2	147.2	106.2	29.53	28.00	0.000
February	127.4	618.3	340.0	139.0	108.1	28.02	28.00	0.000
March	130.7	649.4	386.8	140.6	104.1	27.96	28.00	0.000
April	114.7	575.9	379.5	110.9	102.5	28.04	28.00	0.000
May	109.3	552.3	351.8	125.4	101.3	24.81	27.13	0.870
June	90.0	457.0	393.1	7.4	100.5	28.39	26.88	1.123
July	87.1	443.7	382.4	0.0	97.2	25.83	26.31	1.690
August	90.7	462.1	394.4	0.0	99.8	27.33	28.00	0.000
September	107.0	540.7	404.1	45.4	103.8	30.07	28.00	0.000
October	119.7	602.4	380.6	100.5	106.5	28.00	28.00	0.000
November	126.9	628.8	366.6	130.4	106.9	28.00	28.00	0.000
December	141.3	703.4	379.1	198.1	106.1	27.98	28.00	0.000
Year	1382.7	6917.1	4558.5	1144.8	103.3	27.82	27.69	0.310

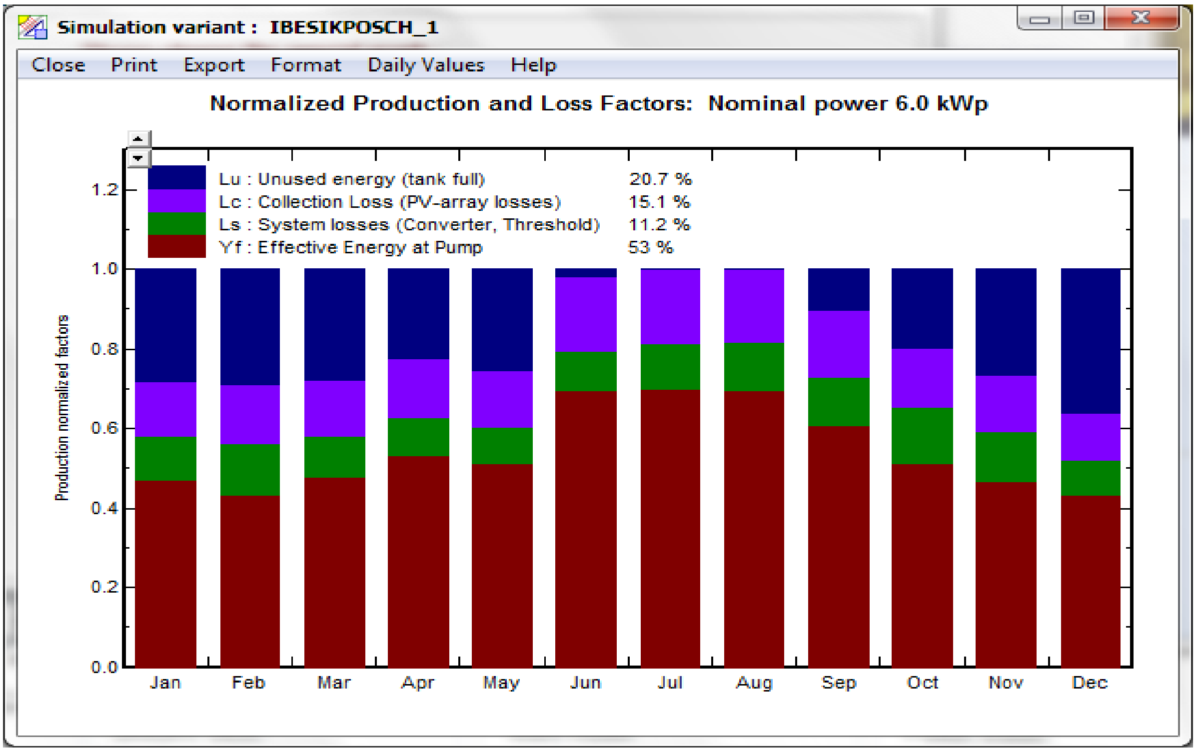

Figure 3 The normalized production and loss factor

V. CONCLUSION

A photovoltaic powered water pump for a remote health facility is presented. The ability of the pump to meet the daily water demand of the hospital is examined along with the technical implications of the selected pump and PV module array. The study used PVSyst software to simulate and provide relevant system parameters for the assessment. In all, the water pump will effectively satisfy the yearly water demand of the hospital with very minimal missing water. However, the month of July has missing water that is slightly above the required annual upper threshold. In any case, the July missing water is not critical as the rainwater in the month of July can easily provide the shortfall in the water supply.

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