Design and Analysis of a PV system for irrigation of a ten Hectare farm in Pakistan

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Abstract: **Farmers in Pakistan are very intent in solar pumps because of the lack of utility power. Photovoltaic panels are in widespread use worldwide for a reliable low-cost electricity generation for irrigation. When properly designed, a PV water pumping system can result in notable long-term cost. In this paper using actual farm data, the design of a stand-alone PV water pumping system has been completed using HOMER Pro. The designed system consists of 78 PV panels with 60 batteries and a 20.7 kW inverter for the pump. The system analysis shows that such a system can meet the watering needs of that farm throughout the year for all type of crops. The dynamic model of the designed system has been simulated in MATLAB/Simulink. Perturbation and the observation-based algorithm has been used for maximum power extraction from PV. Simulation results show that the system can provide a stable voltage and frequency. This research also provides a relative study among all alternative systems economically.**

I. INTRODUCTION

Solar-powered pumps are identified as either positive displacement pumps (e.g. diaphragm, piston, or helical rotor) or centrifugal pumps. Positive displacement pumps are typically used when the TDH is high and the flow rate (measured in gallons per minute) required is low. Conversely, centrifugal pumps are typically used for low TDH and high flow rates. Some underdeveloped countries like Pakistan facing energy crisis [1], these farms are mostly isolated from the grid. Fortunately, areas, where most of the agricultural farms are located, are naturally rich in a solar source which makes them the most suitable to utilize solar energy to gain electricity [2]. First of all, we need to calculate the load which is required by the water pump to extract water out of the ground. Load depends on what kind of crops you are growing throughout the year and how much water is needed by them [3]. To confirm the exact required amount of water we have taken help from [4]

II. SYSTEM DESIGN CONSIDERATIONS

The main parts of a solar-powered water pumping system are controllers, the actual pump, solar panels, the output power which depends on the solar panel input as it varies and the engine [5]. The components of the system design are determined by the solar insolation available at the site.

SYSTEM CONVINIENCE

Pumping system receives electricity from PV modules so no need of a grid. It uses Solar energy to pump water from well. Solar pumping is sized according to the need of the farm and in summer productivity increases when usually water requirement is higher. Batteries can be installed as an option for backup and we can also rely on water storage tank which can store water in pump's idle time and can be used when the weather is cloudy and PV output drops. PV system can reduce or omits electricity bills. They have Diverse applications, technology development and Low maintenance cost as compared it eliminates expenses of fossil fuels (generator based). Feasible for remote locations and last but not the least PV water pumping system is a pollution-free system

III. SIZING, MODELING AND ANALYSIS

For sizing the first thing we need to recognize is the total amount of load required and that can only be reckoned by the total hours of pump working. All of the following work is done in Homer Pro. hourly load and daily water discharge are shown in figure 1 and figure 2 below.

According to these figures, the afternoon is the peak time when the load is the highest and discharge rate of the water is also at its peak

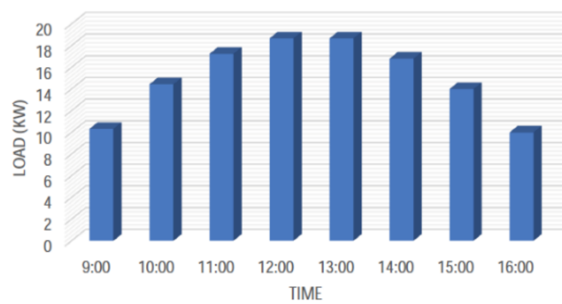

FIGURE 1: HOURLY LOAD (KW)/H

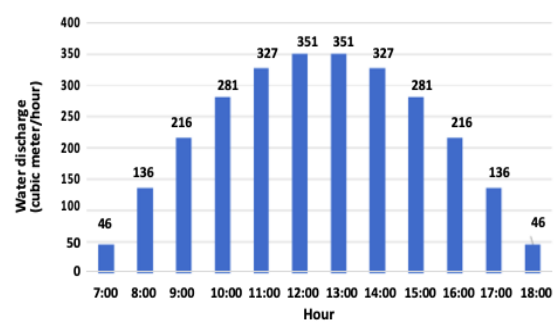

Figure 2: Daily water discharge rate by hours

Figure 3 [6] is showing us monthly solar irradiance for the selected site which is clearly showing us the March, April and May have maximum SI, meanwhile from figure 4 we can also see that hourly SI is at its peak in the afternoon which is also a plus point because in the very same our we need maximum amount of water. We can see hourly water discharge rate from fig. 2 but if we look at the following figure carefully we will see that water discharge rate is comparatively lower in June, July, August and September that's because our site location have Monsoon weather in which there is heavy rain, due to this very reason less water is pumped out because our water need drops, as we need less water in mentioned months so it will also affect the electricity production as shown in figure 5

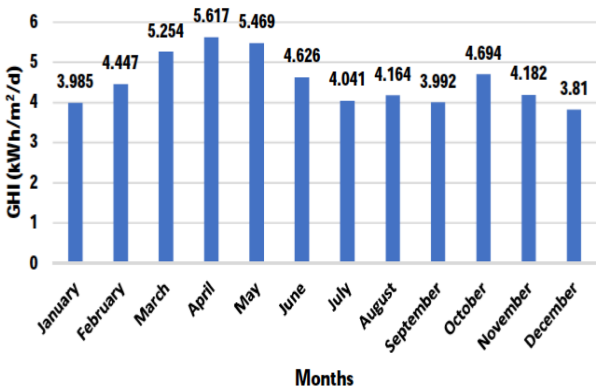

Figure 3: Monthly Solar Irradiance

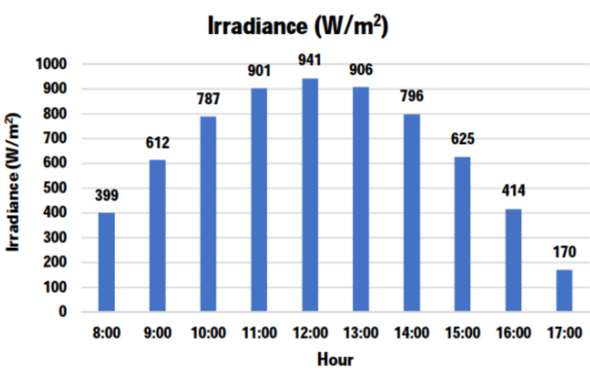

Figure: 4 Hourly Solar Irradiance

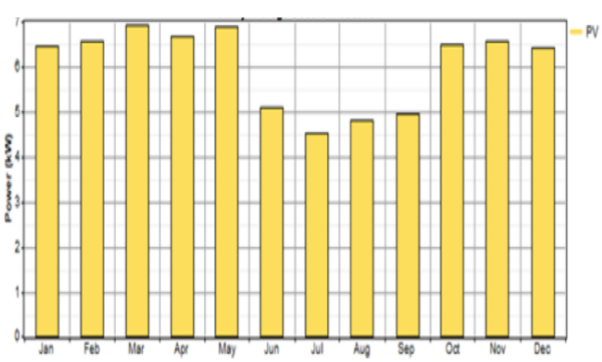

Figure 5: Monthly Electricity Production

IV. SOLAR PANELS

The selected solar photovoltaic panel for the system was from the Crystalline PV module, CHSM6612P Series. The technical specification of the PV module and its state of charge (efficiency) is described in table 1. Selected panels are reliable, cost effective and are suitable for residential, commercial and utility scale PV system.

Table 1: Specification of Crystalline PV

Model number	CHSM6612p
Peak Power [Wp]	310 Wp
Max. Power Current [A]	8.68A
Max. Power Voltage [V]	35.80V
Max. System Voltage [V]	1000 VDC
Cell Temperature [C]	46 C
Efficiency at STC [%]	16
Brand	ASTROENERGY

V. INVERTER

The DC photovoltaic output converted into AC unit by A 20.7 kW chosen inverter (Solar Edge SE10000H). The average output of the inverter was 4.5 kW with a capacity factor of 21.6 %.

VI. BATTERY

The energy can be stored as electrical power stored in batteries [7]. The simulation result implies that the 60 batteries (total of 15 strings, with 4 batteries per string) were used store the electric energy for further use. The specifications of the chosen battery are in

Table 2: Battery specification

Model No.	6FM200D
Nominal Capacity [Ah]	200
Max. Capacity [Ah]	193
Nominal Voltage [V]	12
Min. State of Charge [%]	40
Max. State of Charge [A]	60
Brand	Vision Battery

VII. SYSTEM DYNAMIC SIMULATION

The simulations of the proposed system have been completed in Simulink shown in Figure 6 which is simulated in Matlab [8]. In this simulation the solar panel is connected with the maximum power point tracker (MPPT) and this tracker is connected with the DC bus. The block of the battery bank is connected with the same DC bus and it also has the charge controller and under/overvoltage protection. Converter reduces the harmonics which ensures the power quality and main usage is to convert DC into AC and links the DC and AC buses. In the Simulink simulations, the PV system output is fed to the block of the DC/DC converter with a controller. To control the duty cycle of the converter the breakthrough of the maximum power point tracker (MPPT) has been applied in the same block. It provides the same output DC voltage equal to 48 V and sends to the battery bank under normal performing and battery bank DC/AC inverter. The maximum power point tracker is used with transformer with low pass filter Load PV panel DC/DC converter with and system structure with integrated subblocks. The output voltage of PV is maximum when the system is running at the maximum power point (MPP) under MPPT [8]. PV module voltage and current at maximum power point are 35.8V and 8.68A subsequently and as the selected panels have 72 cells each and per string two panels are connected in series, the bus voltage should be 48V. A total number of strings is determined as 62.

its more available and cheaper prices as compared with the past [10]. In many countries around the world, Government is not charging any

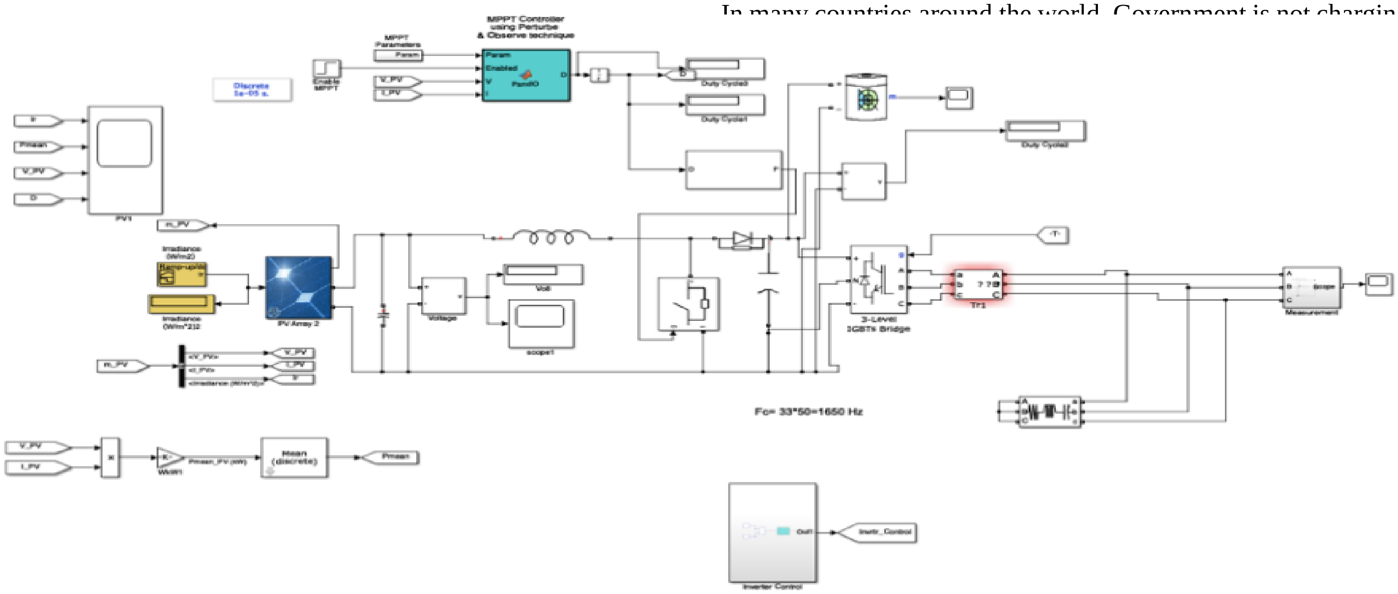

Figure 6: System simulation

tax on importing components for a PV system and on the top of that some Government are helping their people especially farmers by giving them a loan on very lower rates so everyone can excel in the farming. For the PV system that we have designed, following the quantity and the price in Canadian Dollars. According to this time electricity tariff in Pakistan a 15 HP (11 KW) water pump consumes electricity of about 4 Canadian Dollars per hour, so let's say if the pump runs for 3000 hours then electricity bill would be 12000 CAD. By installing this PV powered water-pump we can save a huge amount on our bills. Installation is a one-time, investment but its benefit stay for 25 years as the life expectancy of this system is 25 years other than the batteries. The comparison between most commonly used sources is given below in figure 12 which proves that solar powered water pumps needs more investment, but they are also the eco-friendliest and they have almost no running cost. In future we can also work on a hybrid system [11]

VIII. OUTPUT

The total 52,804 kWh of energy can be produced per year and the AC primary load consumption is 100% (39,110 kWh/yr). The overabundance of electricity is around 15.2 % (8,043kWh/yr) which is not a lot and can be utilized. The PV output ranges from 7.2 kW to 28.8 kW mostly during the production. Although the appraised capacity is 38.4 kW, the average output is about 145 kWh/d with the capacity factor of 15.7 %. Figure 7 is giving a clear perception about the PV output. The average water discharge is 1700 cubic meter per day with a total dynamic head 12m. 26.775kWp solar photovoltaic panel provides enough power to run an 11kW motor-pump set to lift [9]. The yearly output of energy in Kw is shown in figure 8

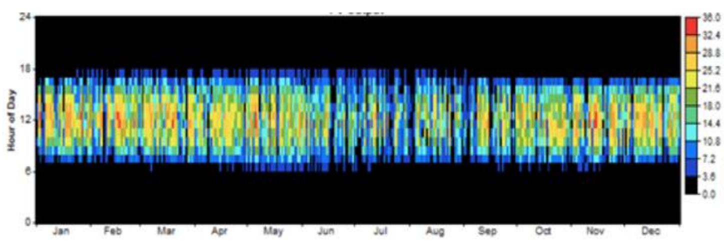

Figure 7: PV output

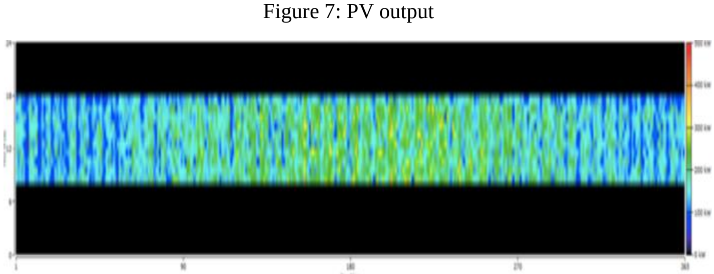

Figure 8: Yearly output

Table 3: Comparative Cost Analysis

Features	Solar-powered	Diesel powered	Grid connected
Investment	High	Low	Low
Running cost	Negligible	High	Medium
Maintenance	Medium	Medium	Medium
	Eco-friendly	Fire hazard	Emits pollution

IX. COST ANALYSIS

A decade back PV energy was not that common and was highly expensive, now due to growing population and technology has made

X. CONCLUSION

People can save their power bills as PV systems are reliable and getting better day by day [12]. Invested capital can be returned just in 7 years rest of the years enjoy PV power for costless minor upgrading in this system is very accessible, so this is a 100% total success.

Watering an area of 10 Hectare can cost up to 7280 – 14000 C.A.D annually including installation and maintenance cost. Installing PV powered water pump one-time cost is 80,000 CAD approximately, will with batteries replacement after every 3 years that can cost up to 10000 CAD approx. Such amount can be taken as loan from P.O.B interest @ 12% Over the time of 25 years we can save thousands of dollars.

XI. FUTURE ENHANCEMENT

PV based solar energy has a lot of potential not only in the field of agriculture but from residential house to big industrial projects can leverage from this. Basic design and components are always the same no matter what kind of application we are working on. We can also add some lights or LED bulbs to this system, adding some sockets would also be an option in case someone is at the site and need to charge phone, laptops etc. A water tank can also be added to this system which can store some extra water in case if the weather is cloudy and we cannot pump enough water then we can use that tank stored water meet our needs [13]. If in future if we have this option then we can also sell our excessive electricity to the grid because after harvesting the crop till planting the next crop we do not need a large amount of water, so very less need of electricity in that time we can get good ROI (return on investment).

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