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Design, Simulation and Economical Analysis of Solar Powered Irrigation Water Pump

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***Abstract*—Irrigation is an age-old technique which is practiced on various levels on farms around the world. It allows variegation of crops while increasing crop yields. A typical irrigation system consume high amount of non-conventional energy by using generators to power the water pumps. Photo-voltaic energy can be used as a substitute of conventional energy. This paper deals with the simple yet effective design of a solar water pumping system in GHAZIABAD for irrigation purpose. In this work, the system for rice and wheat crop has been designed consisting of SPV modules along with maximum power point tracker (MPPT) to attain maximum power efficiency, DC-DC Boost Converter, permanent magnetic DC(PMDC) motor and Submersible pump. The simulation of the system has been done through MATLAB/SIMULINK which verifies the system's functionality along with its components. The study also focuses on the economic evaluation of renewable energy over traditionally used non-conventional source of energy**

***Index Terms*—SPV-modules, Boost-Converter, PMDC motor, Submersible pump , Irrigation System, MATLAB/SIMULINK**

I. Introduction

Dwindling conventional energy resources and Ever increasing energy demand has created a huge gap betweem energy demand and supply.Energy scaracity and rising pollution levels worldwide have forced the researchers to look for options for a green energy production. Agriculture is the backbone of Indian economy. Reliable irrigation is so critical to farmer's livelihood that app. 25 million grid connected and diesel powered pump systems have been installed till date. Replacing these with Solar powered pumps will reduce air pollution, release of green house emissions and help in reducing energy scaracity. For developing countries like India, cost of the overall system plays a huge role in its practical feasibilty. Using plastic or metal tank for water storage purpose insted of using batteries for power storage [2]can help to reduce the cost of the Solar water pump.D.C. motors for Solar water pumps are most cost effective as PV modules produce d.c. which can be directly used by d.c. motors. But,A.C. motors require an inverter which adds to the cost of the whole system [3].Dynamic performance and efficiency of PMDC motor is better than A.C. motor [4].PV pumping system reduces the Net Present Cost (NPC) of the system due to low operation & maintenance cost [8].Water conservation, water saving technology and precision farming can be used to improve the water use efficiency. Different irrigation techniques like drip irrigation [5] makes it further cost effective. Solar water pump gives better performance at MPPT point [6], but, variation in solar radiation makes the efficiency of pump dependent on motor parameters [7].

Based upon literature review, The author have designed a solar energy driving water pump system incorporating a PMDC motor for 20-Quintal of rice and wheat and simulated the design model in MATLAB/SIMULINK. The author have also done an economical analysis between different sources which is used to power the water-pump. The another aim of this paper is to observe the response of pump speed, discharge rate, armature current of motor and power received by the motor with the change in irradiance at constant temperature.

II. Site Location

Ghaziabad is a fast upcoming advanced industrial district of U.P which is located at 28.67deg N 77.42deg E. The solar radiations received by the district in 12 months has been shown in Table 1.

A. Agricultural Profile Of The Location

Ghaziabad is located in the western part of Uttar Pradesh covering an area of approx.1148 sq km. The normal rainfall in this Ghaziabad district is about 732 mm. The State has remarkable bearing on the Agricultural performance. The net sown area is 1.49 lakh ha with a net irrigated area of 1.38 lakh ha, with cropping intensity 172%. Wheat and Rice are the major crops grown in the district.

B. A. Calculation of Solar PV System for Water Pumping

- RICE

20quintal Of Rice Requires = 7000000 Litres For 150days
Load requirements = 47000 litres of water every-day from a depth of 50m

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Amount of water to be pumped/day = $47m^3$

• WHEAT

20quintal Of Rice Requires = 1800000 litres for 150days

Load requirements = 12000 litres of water every-day from a depth of 50m

Amount of water to be pumped/day = $12m^3$

To decide the Total Dynamic Head (TDH)

Maximum elevation of piping unit inlet = 35m

Maximum head of running stream fluctuates = 15m

Total vertical lift = 35m + 15m = 50m

Frictional losses = 5% of total vertical lift = 5 % of TDH = 2.5m+Total vertical lift = 50m + 2.5m =52.5m

For estimating the load requirement with selected DC pump for RICE crop [Experimental]

Selected DC pump max head = 59m

Selected DC pump max flow = $6m^3$/hour

Supplied voltage = 24/36V

Power consumption, P = 750Watt

Required running hour/day = 8 hour/day

Required electrical energy/day

= Power consumption$\times$ Running hour/day

= 750Watt $\times$ 8hour/day = 6 kWh/day

For estimating the load requirement with selected DC pump for WHEAT crop [Experimental]

Selected DC pump max head = 59m

Selected DC pump max flow = $1.5m^3$/hour

Supplied voltage = 24/36V

Power consumption, P = 750Watt

Required running hour/day = 8 hour/day

Required electrical energy/day

= Power consumption $\times$ Running hour/day

= 750Watt $\times$ 8hour/day

= 6 kWh/day

To understand the Ampere hour requirement of DC load System for both crop

Voltage = 36V

Load Current = 20.83A

Required running hour/day = 8 hour/day

Required Ampere hour/day = Load current $\times$ Running hour /day

= 20.83$\times$ 8 hour/day

= 167Ah/day

Module efficiency due to temperature = 21.1 %

Total loss factor = 5

Estimated Ah requirements from PV module

= Possible max Load $\times$ Loss factor

= 167Ah/day $\times$ 5 = 835 Ah/day

Total Ampere requirement from a PV module = 282A

PV module system voltage = 36V

PV module system current = 282A

Required Power capacity of a PV module, P = 10.2kW

Selected PV module unit = 365W

Required numbers of PV modules

= Required PV power module/Selected module = 28 modules

Hence 28 modules can be used in around 800-1000sq.feet of an area to run 1hp of a pump for the discharge of water at the rate of $6m^3$/h to the fields.

TABLE I
SOLAR RADIATION DATA OF GHAZIABAD

Months	Hours	Hours per Day	Kwh/m2/hour	Watt/m2
January	91.8	2.96	3.16	131.66
February	108	3.85	4.90	204.166
March	120.8	3.89	6.28	261.66
April	138.3	4.61	5.83	242.916
May	154.5	4.98	5.40	225
June	149	4.96	4.16	173.33
July	147.3	4.75	2.79	116.25
August	145	4.67	3.53	147.0833
September	111.8	3.72	4.74	197.5
October	98	3.16	4.28	178.33
November	89.8	2.99	3.41	142.0833
December	92.8	2.99	3.07	127.916

III. PROPOSED SYSTEM

The water pump system proposed in this work is a directly-coupled type, without battery backup. A storage tank can be used in place of batteries, to store the water. The SPV water pumping system is designed in this work for irrigation purpose, based on the actual requirement of the water for the crops(rice & wheat).

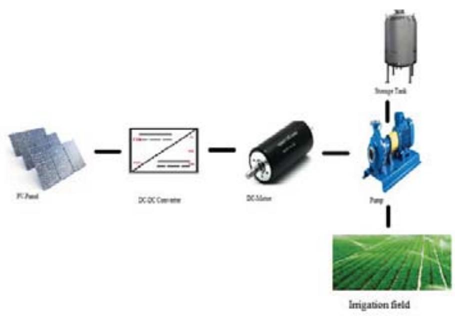

Fig. 1. Structure of SPV Pumping System

Figure 1 shows a very simple pumping system which consists of a photovoltaic module (attached to a maximum power point tracker (MPPT)), DC-DC converter, a DC submersible pump, and a storage tank. An actual size system is designed, which is required at present to fulfill the water needs of the crops for their harvesting period in a year. The theoretical study is done about the system and performance is analyzed in Matlab/Simulink.

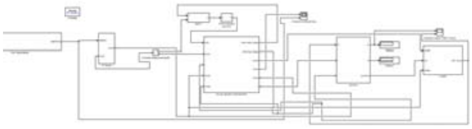

Fig. 2. Simulink Model for Solar Water Pumping System

Figure 2 shows the SIMULINK model of Solar Water pump in which PV-array is connected to a DC-DC Boost Converter along with permanent magnetic DC motor through a MPPT. Each subsystem in this model has its own characteristics and Simulink blocks as shown in APPENDIX(I-IV). The input is taken from spreadsheet which consists of 12 months radiation of the location at a constant temperature of 300K.

IV. RESULTS

The simulation result of solar water pump-system at different radiation and constant temperature has been shown All the results are based out of One Solar Panel. On a similar ground, the full system can be analyzed.

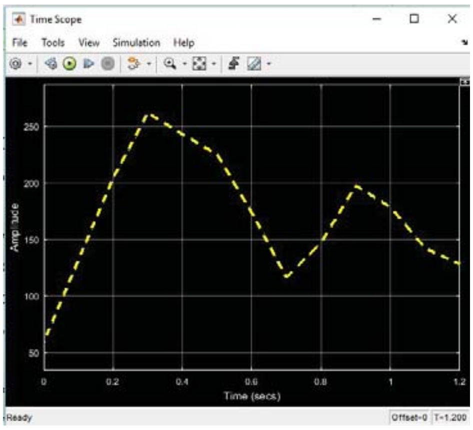

Fig. 3. Solar Radiation Data on the Scope

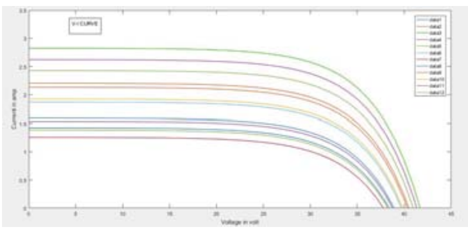

Fig. 4. I-V Curve

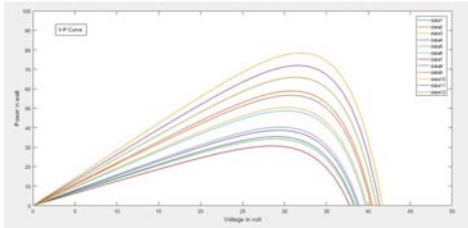

Fig. 5. V-P Curve

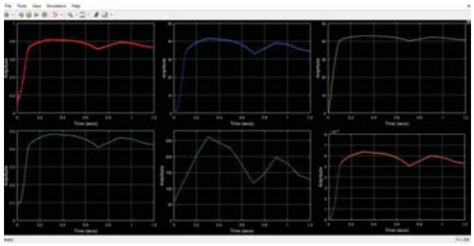

Fig. 6. Outputs After Simulation

Above figures show the results of PV-panels obtained after simulation for input radiations received by GHAZIABAD. Further, these output becomes the input for boost converter which will help to boost up the armature voltage for PMDC motor.

⋆ Solar irradiation is at its peak on 0.32 seconds, where the solar irradiance increases from 204W/m2 to 261W/m2 and correspondingly the input power to the PMDC motor is also increased.

⋆ Since the PV array is directly connected to the PMDC motor through MPPT, the power efficiency will be higher and will cause an increase in the mechanical output torque.

⋆ The current at 0.32 seconds is increased due to the increase of torque which is directly proportional to armature current as shown in Figure.7(a).

⋆ The speed of the rotor is increased proportionally with the increase in the solar irradiation as shown in Figure.7(c).

⋆ Now, with the increase of rotor speed, the flow rate of the submersible pump will start increasing. Figure.7(f) shows the increase of the flow rate when the solar irradiance is increased at 0.32 seconds.

⋆ The power attained by the PMDC motor is decreased when the solar irradiance decreases from 216W/m2 to 116W/m2 because they both are correlated to each other.

All the results show that solar irradiance is the prime concern for the system.

A. ECONOMICAL RESULTS OF SOLAR WATER PUMP

Current economics indicate an IRR of 10% for replacement of diesel pumps with solar pumps without factoring in crop yield improvement benefits due to water availability on demand. However, the capital cost of an SPV pump is about ten times of a conventional pump and hence it requires capital subsidy and financing support but looking at its positive side, it reduces the cost of the whole system in long term. The parameters of the cost analysis for the PV system are as follows; PV unit cost = Rs.50/PV Watt

PV structure = Rs.18/PV Watt

Cabinet & cables = Rs.7/PV Watt

Installation = 5% of the capital cost

O&M = Rs.6700/year (with interest rate of 6 %).

TABLE II
COST ANALYSIS OF PV PUMPING SYSTEM

PV Cost	Rs. 50000/-
PV Structure	Rs. 18000/-
Cabinet& Cables	Rs. 7000/-
Total Cost	Rs. 75000/-
Installation Cost	Rs. 3750/-(5%of the total)
NPC	Rs.78750/-

B. Diesel Systems

Diesel system uses the fuel to drive the water pump for operation. So the total cost of the system includes the cost of the diesel generator, fuel, and O&M. There are two systems one is only PV system and the other is only Diesel unit. Table-3.shows the comparison between the two of assumed 1KW systems.

TABLE III
COMPARISON OF COST BETWEEN PV AND DIESEL SYSTEM

PARAMETERS	PV	DIESEL
SYSTEM COST	Rs. 78750/-	Rs. 32000/
FUEL CONSUMPTION	00	0.7Litre/hr./
FUEL PRICE	00	Rs.0.67/Litre
ANNUAL REPAIR&MAINTENANCE	00(first year)	00(first year)
HOURS OF OPERATION	3600=1800	3600=1800
FIRST YEAR COST	Rs. 78,750/-	Rs. 1,16,420/-

It shows that for an assumed system of 1KW, system cost of PV system is higher than Diesel system but the total first-year cost of diesel system is higher than PV system. In next 5 years, PV system will be beneficial because with an inflation rate of approx. 2

Table.2 shows the results of the economic analysis of the 1KW[assumed] PV system

V. CONCLUSION

Based on the study main conclusions are as follows:

• 28 PV-Modules each of 365Watt with an efficiency of 21%, can be used in the system along with to provide the full power to the 1Hp of DC submersible pump at different solar radiation and water can be store in large storage tanks and can be utilized when no source of energy is available.

• The first year cost of PV system is Rs.78,750 whereas the cost is high for traditionally used Diesel system, that is Rs.1,16,420. The O&M cost of PV system would cost around Rs.8734 whereas for diesel system it would be Rs.1lakh at the end of 5 years at 2% of inflation rate. It shows that Solar based water pump is a dependable alternative solution against diesel water pumps as it reduces the O&M cost of the system which seems to be a feasible solution in the long run.

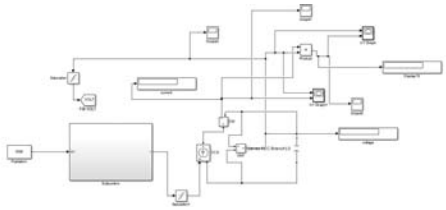

Fig. 7. Simulink diagram of PV Cell

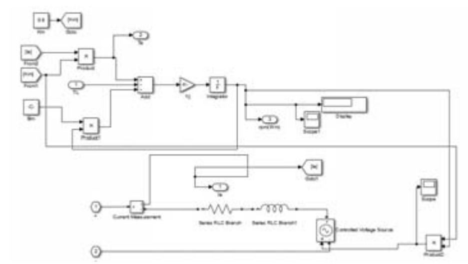

Fig. 8. PMDC Motor

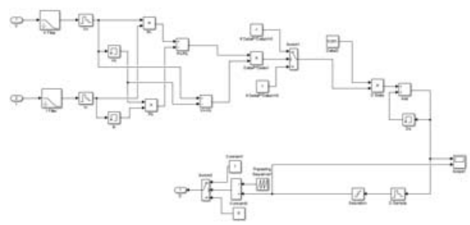

Fig. 9. P&O MPPT Algorithm

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