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NUMERICAL ANALYSIS OF COST-EFFECTIVENESS AND PERFORMANCE OF SOLAR WATER PUMPING SYSTEM IN INDIA

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ABSTRACT

There are some sources of energy to turn on motors; electric and diesel motors are generally used in irrigation. Solar based water pumping system is a convenient and affordable solution used to solve water shortage problems in India. Due to the constantly increasing cost of fuel or high rate of electricity, pumping of water from surface water and groundwater wells has become extremely difficult for farmers and other water users. This paper analyze the viability of Photovoltaic based pumping system in water irrigation with low cost and high efficiency. Solar water pumping system is environment friendly. This system can provide considerable socio-economic benefits to both at farm level and at national level. This study evaluates the performance parameters namely speed, efficiency and power factor of motors. The cost of pumping is the deciding factor in the analysis of the costs of water pumping systems. The result reveled that in compare to diesel pump and electric pump, solar pump is proven as an affordable alternative for water pumping system.

Keywords: *Photovoltaic irrigation systems, Irrigation cost, Efficiency, life cycle cost, Environment-friendly, Reliability.*

1. OBJECTIVES OF THE STUDY

The objectives of this study are to analyze the cost benefit of solar water pump based on the life-cycle cost approach and to evaluate the performance of solar water pump.

2. PURPOSE OF THE STUDY

Because of the fossil fuel resources decline and their great share in environmental pollution and issues, the countries and investigators are looking for green energy resources based on each region’s potentials. However the huge area of cultivable land in India which is needed to be irrigated has no grid connection. Photovoltaic pump could be used for irrigating these lands for better crop production. The best solution is to install solar pumps for irrigation and drinking water purposes in India, in a bid to expand the country's irrigated land area and boost food production, while limiting its trust on fossil fuels.

3. INTRODUCTION

A solar water pump system is basically an electrical pump system in which the electricity is provided by one or several Photo Voltaic (PV) panels. The water supplied by the solar water pump can be used to irrigate crops, water livestock or provide potable drinking, cooking and sanitation water. Solar water pumps can replace the current pump systems and result in both socioeconomic benefits as well as climate related benefits.

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The Photovoltaic System:

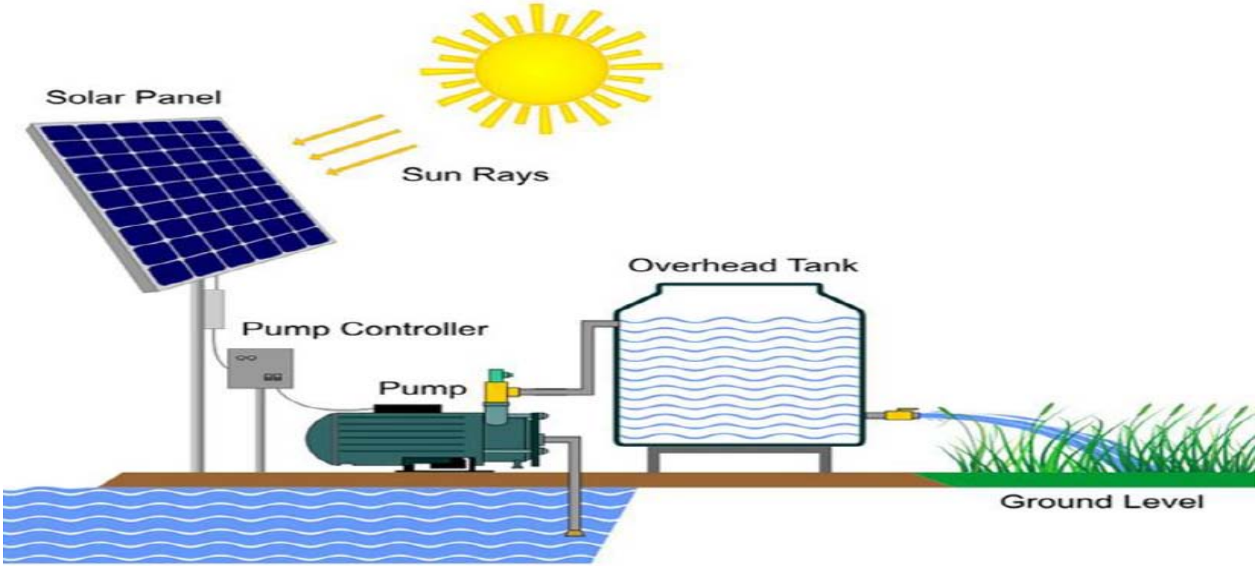

Figure-1: The Photovoltaic system

Figure-2: Submersible pumps

4. METHODOLOGY

4.1. Cost effective and environment-friendly

Solar pumps are smart alternative technology for irrigation, which serves as a cost effective mode of irrigation with low maintenance requirements. Irrigation is a major input cost in agriculture amounting to about 70 percent of the total cost. The use of solar-powered pumps can decrease the input cost to 25 percent. For a small and marginal farmer, this is considerable and can be a game changer in making small and marginal farming more remunerative.

Efficient water use in agriculture is also critically important for the sustainability of agriculture, particularly in water-stressed regions. In irrigation, the burden on the groundwater reserve will be reduced by water saving technology and also improves water security. These technologies have the potential to save water in India. So, lower cost of inputs, zero carbon footprint [8], unattended operation and easy accessible irrigation water for poor farmers are the important benefits of solar water pumps. The use of solar water pumps combined with the usage of appropriate technologies such as zero tillage, laser leveling and water conservation at the local level can be very useful for water and agriculture in India.

4.2. Reliability:

Maintenance, high fuel costs or high rate of grid electricity have been long-standing problems with diesel pump and electric pump. The systems are often in remote area; therefore people face the difficulties of purchasing imported spare parts and fuel, which make them unreliable. Diesel pumps require more maintenance and attention. Depending on the system, a pump engine may need to run for long periods of time which would require constant refueling of the engine along with regular checking of oil levels/filters. Diesel pumps are not a real alternative solution, as they don't meet the demand of rural population and have other negative side effects like high cost of operation, a susceptibility to break down , poor and expensive maintenance servicing and not environmentally friendly. A major service includes decarbonisation, adjustments, oil change and filters replacements and requires skilled personnel which are assumed to be in the region or at a close-by service center. Farmers value the reliability of electricity but they are also not willing to pay a higher price. The cost for electricity varies according to where and when it is consumed. There is also an uncertainty with regard to how expensive electricity will be in the future.

Water pumping has long been the most reliable and economic application of solar (PV) systems. Batteries are not used in most of PV pumping systems; the PV modules power the pump directly. Instead of storing energy in batteries, water is pumped into storage reservoirs for use when the sun isn't shining. Most of the maintenance reduced by eliminating batteries from the system. Eliminating batteries from the systems reduced about 1/3 of the system cost. Without batteries, the PVP system is very simple. The PVP system consists of only three components: the pump, the solar array and controller. The only moving part is the pump. The solar modules are continuously produce energy for 20-25 years. The expected life of most controllers is 5-10 years. Pump life can vary from 5 to10 years and many are designed to be repaired in the field**.** The solar modules are required cleaning for every 2-4 weeks. This task obviously can be done cheaply by non-skilled local labor. Normally the maintenance required if the pump or controller fails.

4.3. Life cycle costing Structure:

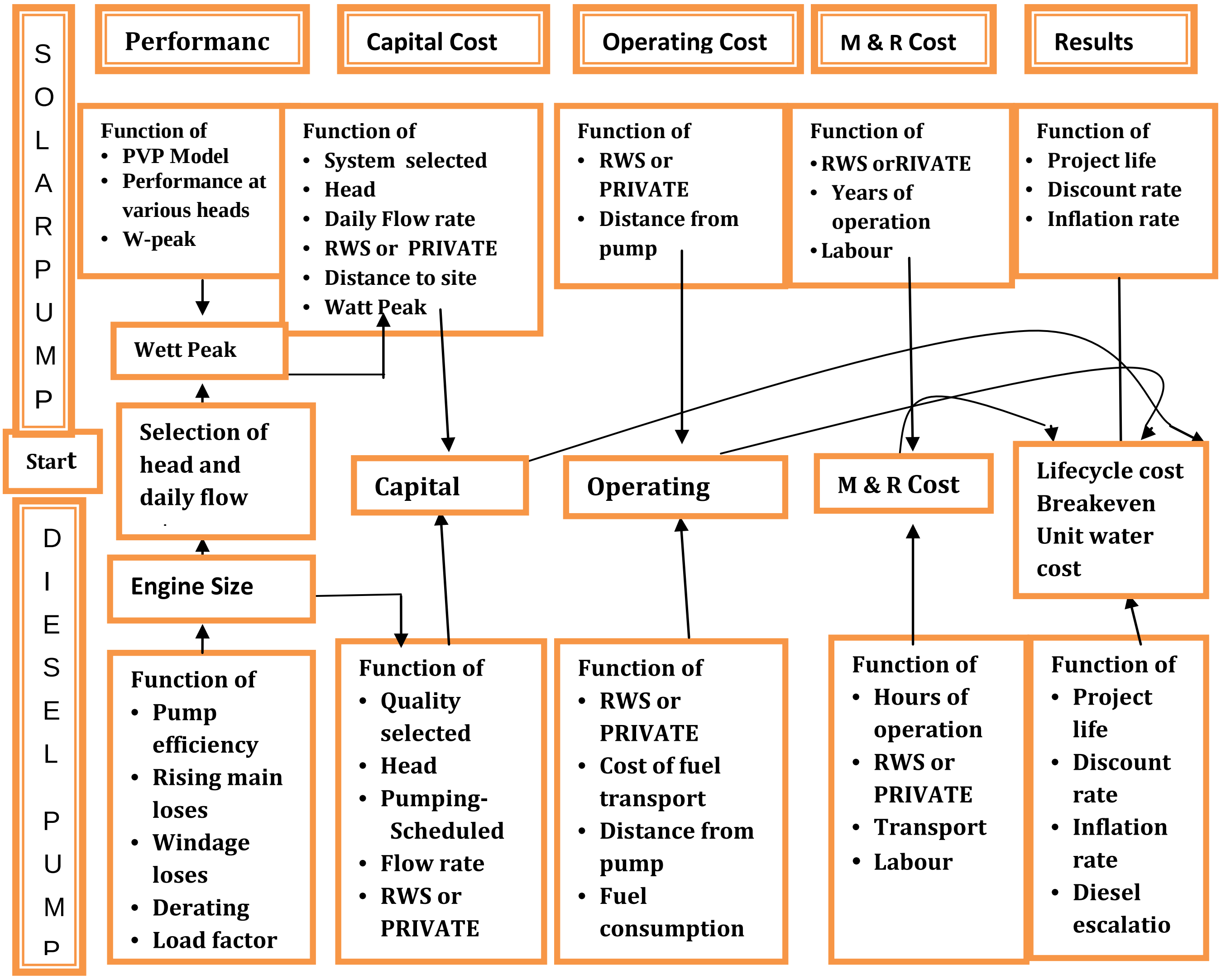

Figure-3: Life cycle costing Structure

4.4. Costs comparison:

Life cycle cost analysis was carried out for economic comparison between solar PV and the diesel pumping system. These costs include the capital cost and the future costs, which include the operating cost, maintenance cost and the replacement cost. The capital cost occurs once at the beginning of the project. It comprises the cost of the equipment and accessories, the cost of the installation and the cost of transport. The maintenance and replacement of the pumping systems are applicable to both the PVP and diesel pumps. The operating costs of the diesel system are more than the solar water pumping system when considering the maintenance and replacement costs. The maintenance schedule and details are dependent on the technology employed. The replacement costs for the pump, motor and controller are equivalent to the initial purchase cost. The service includes the tasks of a minor and major service, replacements of parts and requires skilled personnel. The service interval depends on depth of installation, water quality and the pump system.

4.5. Costs analysis of water pumping systems using solar energy and diesel oil

The cost comparisons show that the diesel pumps are more expensive than solar pumps for pumping the same average amount of water per day. M.A. Hossain (2015)[3] addressed that the initial cost was the major cost (45%) in solar irrigation system followed by installation (18%), motor (16%), pump (10%), pipes and fittings (4%). S. Harishankar (2014) [7] concluded that though the initial investment is higher in case of solar water pumping system, it can be earned back within two and half years. If the excess energy is sold to the national grid, it will add to the revenue of the farmers. The benefit-cost ratio of the solar pump is also higher than the diesel-operated pump or electric pump.

Items / Lift systems	Electric motor (R$)	Diesel motor (R$)
Initial cost	38,404.70	7,976.7
Cost of maintenance /operation	25,527.23	8,513.56
Cost of pumping	-	51,552.01
Total	63,931.93	68,042.28

4.6. Efficiency calculation of solar pump and regular pump:

	Regular Pump					Solar Pump				
No Load Test	1	2	3	4	5	1	2	3	4	5
1) Voltage	415	415	415	415	415	380	380	380	380	380
2)Cold Resistance	3.45	3.45	3.45	3.45	3.45	2.7	2.7	2.7	2.7	2.7
3) Temp. Cold(°C)	32.7	32.7	32.7	32.7	32.7	29	29	29	29	29
4) Input (Kw)	0.618	0.618	0.618	0.618	0.618	0.570	0.570	0.570	0.570	0.570
5) Current (Am)	5.38	5.38	5.38	5.38	5.38	5.37	5.37	5.37	5.37	5.37
6) I^R Losses	0.100	0.100	0.100	0.100	0.100	0.078	0.078	0.078	0.078	0.078
7) No Load Losses	0.518	0.518	0.518	0.518	0.518	0.492	0.492	0.492	0.492	0.492

Efficiency Calculation:										
	Regular Pump					Solar Pump				
1) Reference Temp(°C)	29	29	29	29	29	29	29	29	29	29
2) Resistance At Ref	3.40	3.40	3.40	3.40	3.40	2.7	2.7	2.7	2.7	2.7
3) F.L.Current (Am)	5.0	5.8	6.2	6.5	6.5	5.8	6.6	7.1	7.2	7.4
4) F.L.Input (Kw)	1.991	2.776	3.1	3.316	3.493	2.018	2.808	3.064	3.368	3.519
5)St. I^R Losses (Kw)	0.085	0.114	0.131	0.144	0.144	0.091	0.118	0.136	0.140	0.148
6) Stator Losses (Kw)	0.603	0.633	0.649	0.662	0.662	0.583	0.610	0.628	0.632	0.640
7) Full Load Speed (Rpm)	2400	2480	2518	2647	2666	2462	2541	2618	2662	2692
8) Frequency (Hz)	41.16	43.49	44.43	45.78	46.22	40.4	42.8	44.2	45	45.5
9) Sync. Speed (Rpm)	2469	2609	2665	2746	2773	2424	2568	2652	2700	2730
10) Slip	0.028	0.049	0.055	0.036	0.038	-0.015	0.010	0.012	0.014	0.013
11) Rotor Cu. Losses(Kw)	0.039	0.106	0.136	0.096	0.109	-0.022	0.023	0.031	0.039	0.040
12) Stray Losses (Kw)	0.006	0.010	0.012	0.013	0.014	0.007	0.010	0.012	0.013	0.014
13) Total Losses	0.649	0.750	0.797	0.772	0.785	0.568	0.644	0.672	0.684	0.694
14) Output	1.342	2.026	2.303	2.544	2.708	1.450	2.164	2.392	2.684	2.825
15) Efficiency (%)	67.39	73.00	74.29	76.73	77.51	71.87	77.07	78.08	79.68	80.27
16) Power Factor	0.555	0.667	0.696	0.711	0.748	0.529	0.647	0.656	0.712	0.723
17) Load (%)	36.26	54.77	62.24	68.77	73.18	39.20	58.49	64.66	72.53	76.34

Description of terms:

Rating = 3.7
Number of pole = 2
Reference Temp = 29^0
Resistance at Ref = 2.7
Multiplier: Star = 3, Delta = 1
Efficiency = Output/Input * 100
Output = Input-Total Losses
Load = Output/Rating*100

Stator I^2R Losses = Full Load Current x Resistance at Reference Temperature
Stator Losses = Stator.I^2Rlosses + No Load Losses
Synchronized Speed = 120 x Freq / Pole
Slip = (Synchronized Speed – Full Load Speed)/ Synchronized Speed
Rotor Cu. Losses = (Input- Stator. Loss) x Slip
Stray Losses = (Input- St. Loss) x 0.005
Total Losses = Stator Losses+ Rotor Cu. Losses + Stray Losses
Power Factor = Input x 1000/(Sqrt(3) x Voltage x Current)

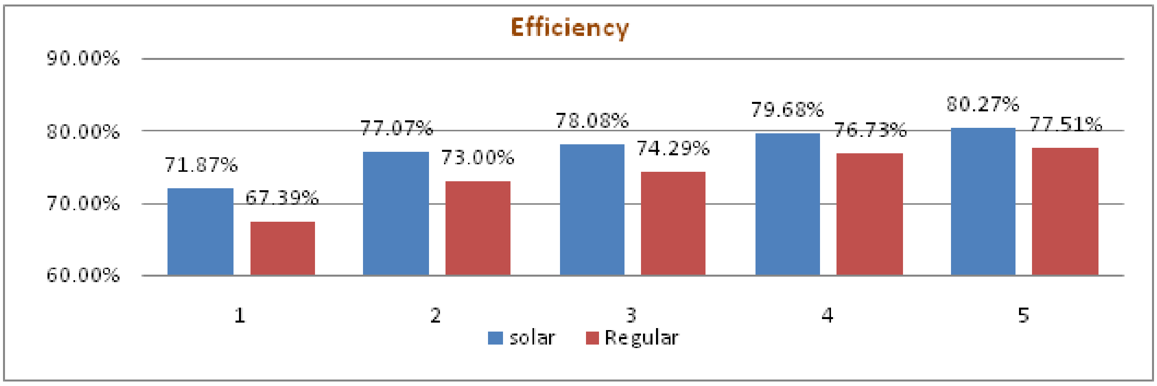

Chart-1: Efficiency comparison of solar pump with regular pump

5. RESULT AND DISCUSSION

The water pumping system that used solar energy had lower total costs and lower overall energy consumption. The solar pump is more efficient than regular pump. The result clearly points out that in comparison of solar pumps, diesel pumps and electric pumps, solar pumps have significantly longer life expectancy and continue to produce electricity for longer time.

The drawback of the Regular pump is the high maintenance cost and lower life of operation resulting in increased running cost and decreased reliability when used for irrigation. Unfortunately, diesel pump contributes to air pollution, global warming, and even soil and groundwater pollution due to spills. Solar pump can be used to defeat this drawback and the same can be used for a wide range of applications. The reliability of the solar pumps is higher while the maintenance requirements are lower. The solar pumps are Envioururnment friendly. Solar pumps are easy to install, do not require nonrenewable energy, and operate autonomously. With recent technical developments in the PVP sector and with the anticipated increase in the diesel fuel prices as well as possible shortages and the high rate of electricity, the breakeven period of the PVP is lower than expected.

6. CONCLUSION

Solar energy system offers an alternative way for sustainable development of a country. This research indicates that the solar water pumping system can be integrated to irrigation systems in India as it is a feasible solution for a longer period. For twenty five years of the life cycle, solar PV system will cost half of the diesel engine operated system. The solar water pumping system for irrigation is the economically feasible solution to meet the irrigation challenges faced by Indian people.

7. REFERENCES

1. Biswas, H., Hossain, H. (2013); "Solar Pump: A Possible Solution of Irrigation and Electric Power Crisis Of Bangladesh", *Int J Comput Appl* 62(16), PP.1–5.
2. Dinara Grasiela Alves *et al* (2014); "Cost Analysis of Water Pumping Using Solar Energy and Diesel in Drip Irrigation", *IRRIGA* 1(1), PP.125-133.
3. M.a. Hossain, *et al.* (2015); "Feasibility of Solar Pump for Sustainable Irrigation In Bangladesh", *Int J Energy Environ Eng*. 6:, PP.147-155.
4. M.Abu-Aligah, (2011); "Design of Photovoltaic Water Pumping System and Compare it with Diesel Powered Pump", *Jordan Journal of Mechanical and Industrial Engineering*, 5(3), ISSN 1995-6665, PP. 273 – 280
5. Md Tanvir Arafat Khan *et al*.; (2012); "Design And Performance Analysis Of Water Pumping Using Solar PV", *2nd International Conference on the Developments in Renewable Energy Technology (ICDRET)*, Dhaka, 2012, PP. 1-4.
6. R. J. Chilundo *et al.* (2018); "Design and Performance of Photovoltaic Water Pumping Systems: Comprehensive Review towards a Renewable Strategy for Mozambique", *Journal of Power and Energy Engineering*, ISSN 2327-5901, 6, PP.32-63.
7. S. Harishankar, *et al.*, (2014); "Solar Powered Smart Irrigation System", *Advance in Electronic and Electric Engineering*, Vol. 4(4), pp. 341-346,
8. Tushaar Shah (2009); "Climate Change and Groundwater: India's Opportunities for Mitigation and Adaptation Environ". *Res. Lett.*4 PP. 13.

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