Journal of Engineering and Applied Scientific Research
ISSN: 2384-6569
Volume 11, Number 1, 2019

OVERVIEW OF THE DESIGN AND SIMULATION OF SOLAR POWERED WATERPUMPS FOR BOREHOLES

Abubakar Jibrin Abdullahi, Tanimu Garba Ibrahim, and Aminu Omeiza
Department of Mechanical Engineering, College of Engineering, Kaduna Polytechnic
E-mail: abdrrrauf35@gmail.com

ABSTRACT
Recent studies confirm that fossil fuel consumption accounts for the majority of greenhouse gas emissions which have largely contributed to global warming. Therefore, utilization of renewable sources is vital today. A step towards increasing the share of renewable energy in the energy mix is the design of solar powered pumps which is discussed in this research. The basic principle of a solar pump is to utilize the energy generated by the solar panel and stored in the battery. The charged battery acts as a fuel tank and is used to supply electricity to drive the pump that supplies water for commercial, industrial and agricultural use. This paper has discussed from past literature the use of modeling and simulation to determine the performance of a photovoltaic pump, and produced a model for solar water pumping system and simulates the results that will gives a PV size, pump size and pump efficiency and the cost of providing water.

Keywords: Photovoltaic, solar pump, submersible, cost of energy, renewable, panel
Received for Publication on 1 March 2019 and Accepted in Final Form 15 March 2019

INTRODUCTION

The continuous rise and competitive demands for fossil fuel necessitate the need for alternative source of energy on earth. In many parts of the world there is a growing awareness that renewable energy have an important role to play in the provision of social amenities such as potable water and electricity for the rural dwellers. Among the various types of renewable energy, special attention has been given to solar energy because it is freely available. According to [15], solar energy is the driving force behind several of the renewable forms of energy. Solar energy is an ideal alternative source of energy because it is abundant and inexhaustible

Nigeria like most tropical countries is blessed with large amounts of sunshine all year round. For instance, Nigeria receives about 490 W/m2 of sunshine per day [14]. From the research carried out by [18], a very high insolation as much as 37639 kJ/m^2 in August was attained in Makurdi, Nigeria. Therefore, positive results are expected from solar energy utilization in Nigeria. The use of photovoltaics for water pumping is appropriate as there is often natural relationship between the availability of solar energy and the water requirement. The water requirement increases during hot weather periods when the solar radiation levels are highest and the output of the solar array is at a maximum. Photovoltaic water pumping systems are particularly suitable for water supplies in remote areas where no reliable electricity supply is available. Water supply through solar pumps is more suitable for drinking purpose than stream water, because this water is pumped from treated boreholes

and wells into an overhead tank where it will finally be treated to WHO required standard before circulation.

Modeling and Simulation

A model is a physical, mathemat ical, or logical representation of a system, entity, phenomenon or process [3]. Simulation is the im plementation of a model over time. Simulation brings a model to life and shows how a particular object or phenomenon will behave. It is useful for testing, analysis or training where real-world systems or concepts can be represented by a model.

LITERATURE REVIEW

[6] Presented an overview of the occurrence of different groundwater sheds, water quality, and availability in Nigeria. It also discusses the viability of solar-powered groundwater pumping systems in Nigeria. Applicable methods for system design and economic analysis are further outlined considering the abundance of water and solar energy in Nigeria, groundwater pumping using the photovoltaic system appears to be a viable means of providing water for the Nigerian populace, especially in localities where the national electricity grid is not yet connected. The methods outlined in this paper for groundwater pumping system design and economic analysis can be applied.

[5] Describes Photovoltaic pumping system as an alternative source of potable water to stream water normally consumed by rural dwellers in Nigeria. A general method for designing simple photovoltaic pumping systems suitable for rural application is developed. The pumping system is based on photovoltaic receiver driving electric pump. Also, information available from PV module and pump-motor. Manufacturers

were used in the design analysis. With this method it is possible to predict the fluid flow rate at any given environmental condition. The problems of lack of potable water in the rural area and the applications of solar pump for village water supply and irrigation are discussed.

[4] His designed model deals with solar powered submersible pump. Among many available schemes, it consists of a PV panel, a storing backup, a variable-frequency inverter, a charge controller and induction motor coupled with a water pump. The inverter drives the induction motor, which drives the water pump. To obtain maximum output power of the Solar panel, the inverter is operated at variable frequency or soft start to minimize stall current of induction motor. This designed model powers 0.75hp water pump. Different types of controllers can be used to increase frequency gradually from 0 to 50 Hz with 5 sec of delay each, thus voltage is controlled from 0 to 220V AC.

[1] carried out study using a software package called PVSYST version 5.5. The result of the study predicted a pumping efficiency of 65.8%. Except for the months of April, May, June, July and August which usually fall within the rainy season and water is expected to be sufficient, the system predicted adequate water supply for pepper irrigation in other months where dearth of water is always experienced. It was concluded that: irrigation farming using solar powered water pumping system is feasible in Kaduna.

[3] Explained in his paper that, theoretical design, performance and simulation analysis of PV based water pumping system with the use of the computer software PVSYST is carried out. According to the analysis, the

solar water pumping system has a system efficiency of 21.9% which is in fair agreement with the previous literature He concluded that A detailed analytical investigation of a typical solar water pumping system (SWPS) is carried out in order to realistically estimate the solar PV sizing for the proposed installation. PVSYST software is used to design and perform simulation of water pumping system.

[6] Discussed and explained that Photo-voltaic (PV) water pumping systems have the advantages (over conventional pumping systems such as those which use fossil fuels) of being of low maintenance, easy to install, simple and reliable, incurring no fuel costs or spills, and requiring unattended operation most of the time. The reliability of PV pumping systems is such that 20 to 25 year power warranties are typical, with life expectancies beyond 30 years.

In India, more than 500 solar pumping systems have been installed for village water supplies. The report of research carried out in these villages after the installation of solar pumps, shows drastic reduction in the occurrence of water related health problems such as typhoid, diarrhea, dysentery and cholera. Three different photovoltaic pumping system configurations are currently in use; the maximum power point tracker (MPPT), the battery buffered system and the direct coupled system. Direct coupled systems are the subject of this paper because they are simple, reliable and the most suitable for rural application [19].Many researchers have in recent times investigated and proposed different methods for designing and optimizing the photovoltaic (PV) pumping system, [13] analyzed a direct coupled

pumping system under steady state conditions. [13] have examined the starting characteristics of PV powered DC motors and pumps both with and without MPPT. [24] showed that a DC motor driving a centrifugal pump represents a well-matched load for a PV array because this system utilizes most of the DC power generated by the array.

[12] Reported that a load composed at a DC motor driving a constant volume pump represents a non-matched load to a PV array because the motor driving constant volume pump requires an early constant current. The matching of a DC motor to a PV generator to maximize daily gross mechanical energy is reported by [25]. [19] Analyzed the performance of photovoltaic pumping system by varying the motor characteristics. In their study, hourly radiation data for a year were required, leading to extensive use of computer simulation time. In another study of solar radiation utilization by [21], two straight line segments were used to represent the nonlinear flow rate versus radiation relationship. However, the nonlinear relationship among these design models is complicated, requiring numerical skill to successfully simulate systems over extended time periods. In addition, it is difficult to obtain the necessary input parameters for the motor and pump models based on available data. Therefore, there is need for simplified design model which is suitable for rural application. The aim of this work is to develop a general method for designing simple photovoltaic pumping systems. In addition, is to analyze the problems associated with the drinking of polluted water by the rural dwellers in Nigeria, and the possibility of using

photovoltaic pumping system to alleviate the problems.

Elena Ciprés Lechuga (2011) Explain that the performance is lower in the months of greatest solar radiation. This occurs because the overall performance of the plant is largely influenced by the temperature of the photovoltaic cells. These cells decrease their performance when their temperature exceeds 25 °C, so in summer, when they reach a temperature of 41 °C, the performance is significantly reduced.

MATERIALS AND METHOD

The methodology involves sourcing of data for inputs parameters

The system input parameters

1. **Geographical Details** [Meteorological]
2. **Well characteristics**..
3. **Storage Tank.**
4. **Pump**
5. **Hydraulic circuit** The Hydraulic Power It's the power required for lifting a volume of water through a given head.
6. **Total Dynamic Head** It is the total equivalent height that a fluid is to be pumped
7. **PV Array characteristics**
8. **Usage of PVSYST, Homer or Mathlab** for the simulation
9. **HOMER SYSTEM** to obtain net present cost and cost of energy. From these results we can easily see which system is most feasible for any given location through a payback period.

HOMER System Modeling Tool

HOMER is a hybrid system modeling tool developed by NREL (National Renewable Energy Laboratory).. HOMER is a micro grid optimization and modeling tool, it takes user data in the form of different component prices, lifetime, grid extension cost, storage system

cost, load profile of location and weather data of the selected location. Using this data, HOMER performs calculations and provides results. HOMER can perform mainly three types of calculations known as simulation, optimization and sensitivity analysis. In simulation, At its core, HOMER is a simulation model. It will attempt to simulate a viable system for all possible combinations of the equipment that you wish to consider. Depending on how you set up your problem, HOMER may simulate hundreds or even thousands of systems. HOMER simulates the operation of a hybrid micro grid for an entire year, in time steps from one minute to one hour. HOMER compares the energy supply and demand for every hour of year and decides how to operate dispatch able sources (generators, battery and grid).In optimization, HOMER simulates each system configuration and sorts by net present cost (NPC), whereas in sensitivity analysis, In sensitivity HOMER makes it easy to compare thousands of possibilities in a single run. This allows you to see the impact of variables that are beyond your control, such as wind speed, fuel costs, etc, and understand how the optimal system changes with these variations. And performs an optimization for each sensitivity variable.. HOMER's results show complete comparison of various given systems and their alternate configurations sorted with respect to their NPC and COE (Cost of Energy).From these results we can easily see which system is most feasible for any given location through a payback period.

10. Earth Imager iterative Software to obtain depth of water

ADVANTATGES AND DISADVANTATGES OF SOLAR PHOTOVOLTAIC ENERGY

The advantages and disadvantages that pose the use of solar photovoltaic energy have a positive balance. It has to be considered that we are facing an energy obtained from a free and inexhaustible source, the sun, and it offers good opportunities for business, private and industrial. It has absolute universality since a photovoltaic plant can be installed anywhere over the Earth and its production will depend on the environmental factors of the area. In addition, as mentioned above, it is capable of providing electricity to all those places where the access to the electricity grid is complicated.

Nowadays, the stronger advantage for humanity is the fact that it is a clean energy. It doesn't emit harmful gases and it avoids CO2 emissions that would be emitted if instead of generating electricity with photovoltaic technology, it would be generated from fossil fuels. Thus, streamlines the independence of oil imported and avoids territorial disputes caused by the need of oil. Another positive aspect of this technology is the low maintenance required. As mentioned above, photovoltaic modules also work with both direct and diffuse solar energies on cloudy days. Finally, it is important to remember that after installing the photovoltaic system, it doesn't require additional investment. If the electricity demand increases, it is simply required to increase the number of photovoltaic modules correctly connected.

The only disadvantage of this technology is precisely the high initial investment to be implemented and the variability of generation due to the variability of the source, since it

depends on solar radiation and climate factors.

CONCLUSION

Water pumping from a PV array is a valid option to pollution-generating diesel and human-powered water pumps. The application of photovoltaic is increasing in rural areas due to shortage, unavailability and costly electricity. Solar powered water pumps are commonly used in agriculture and residential level. Many researchers have produced a model for solar water pumping system and simulated the results that give a PV size, pump size and pump efficiency and the cost of providing water.

RECOMMENDATION

Solar energy could be made to play crucial role in the supply of potable water to the rural areas. Most rural dwellers rely only on the polluted stream water in their villages for drinking and for other domestic purposes. Therefore, they are exposed to various health problems associated with drinking of polluted water. Solar photovoltaic pumping offers a way out to the people from the energy crisis. Numerous technological challenges were overcome through engineering solutions and finally a representative model of system is built which can be implemented in the field. Upfront cost of the solar pumping system potentially hinder to popularize the system in the rural areas but private companies, bank and govt. can come forward for a solution that can fit to rural people.

REFERENCES

1 Adu, M. R., Bolaji, B. O. (2004). Possibility of rural electrification through solar energy in Nigeria. *Proceedings of 5th Annual Engineering Conference of School of*

Engineering and Engineering Technology, Federal University of Technology Minna,Nigeria: 105 – 111.

2 Anis, W.R., Mertes, R., Vas Overstacten,R. (1985). Coupling of a volumetric pumpto a photovoltaic array. *Solar Cells*. 14(1):27 – 42.

3 Appelbaum, J., Bany, J. (1979). Performance analysis of direct coupled PV pumping system. *Solar Energy*. 22(1): 439 –445.

4 Bamiro, O. B., Ideriah, F. J. K. (1982). Determination of the optimum collector orientation

5 for Ibadan Nigeria. *Nigerian Journalof Solar Energy*. 2(1): 26 – 32.

6 Bather, D. M., Caruthers, S. P. (1981). Energy from agriculture; catch crops as a potential

7 Fuel source in the UK. *Proceedings of the International Seminar on Energy Conservation and the use of Solar and other Renewable Energies in Agriculture* ;Polytechnic of Central London. PergamonPress Ltd., England: 9 – 22.

8 Duffie, J.A., Beckman, W.A. (1991). *Solar Engineering of Thermal processes*, 2nd edition, Wiley Interscience. New York.

9 Elena Ciprés Lechuga (2015) Analysis of the implementation of a photovoltaic plant in catalona Politechnika Łódzka MASTER THESIS

10 Esrey, S.A., Potash, J.B., Roberts, I.,Shiff, C. (1996). Effects of improved water supply and sanitation on ascariasis, diarrhoea,dracunculiasis, hookworm infection, schistosomiasis and trachom. *Bulletin ofthe World Health Organisation*(WHO). 69(5): 609 – 621.

11 Fagbenle, R. (1991). Optimum collector tiltangles and average annual global radiationfor Nigeria conditions. *Nigeria Journal ofRenewable Energy*. 2(1): 9 – 17

12 Hsiao, Y.R., Blevins, B.A. (1984). Direct coupling of photovoltaic power source to water pumping system. *Solar Energy*. 32(4): 489 – 498.

13 Heather, M (2003):"Low Cost Irrigation Technologies for the Poor"; DFID Knowledge and research programme (KAR) R7392, pp. 1-57

14 1b. O. Bolaji and R. Adu (2017) Design methodology for photovoltaic pumping system suitable for rural application innigeria asset series b (2007) 6 (2): 120-130

*15*J.I. Sodiki et al. (2014) Solar-Powered Groundwater Pumping Systems for Nigerian Water Sheds INTERNATIONAL JOURNAL of RENEWABLE ENERGY RESEARCH, *Vol.4, No. 2, 2014*

16 Klein, S.A. (1996). *TRNSYS Users ManuaN*ersion 14.2, University of Wisconsin solar energy Laboratory, Madison, W.I.

17 Loxsom, F., Durongkaveroj, P. (1994).Estimating the performance of photovoltaic pumping system. *Solar energy*. 52(2): 215 – 219.

18 Mansaray, K. G. (2014):"Optimum Design of Solar Photovoltaic Pumping Systems by Computer Simulation"; International Journal of Emerging Technology and Advanced Engineering, vol.4, issue 9, pp. 2250-2459.

19 Naveen Kumar Lodha1, K. Sudhakar2 (2013)Theoretical Design and Simulation Analysis of PV Based Pumping System for Domestic Applications in Bhopal, M.P, India International Journal of Science and Research (IJSR) ISSN (Online)

20 Oyefolahan Ahmed Oyedokun, Achara. N. Muhammed .S.U., Oyefolahan Ishaq.O.(2017) Design and Simulation of Solar Powered Water Pumping System for Irrigation Purpose in Kaduna, Nigeria. International Journal of Scientific Engineering and Technology ISSN : 2277-1581 Volume No. 6, Issue No. 10, PP : 342-346

21 Oguntoke, O., Ogunwede, Y.A. (2003).Impact of unsanitary waste disposal on the health of rural dwellers. *Proceedings ofthe 11th Annual Conference of Environmentand Behaviour Association of Nigeria*(EBAN). November 2003: 129 – 133.

22 Q-Kou, S., Klein, S.A., Beckman, W.A. (1998). A method for estimating the long term performance of direct-coupled PVpumping systems. *Solar Energy*. 64(1): 33– 40.

23 Roger, J.A. (1979). Theory of the direct coupling between DC motors and photovoltaicsolar arrays. *Solar Energy*. 23(3):193 – 198.

24 Richard, G. A., Luis, S. P., Dirk, .R. and Martin, S. (2006):"Crop Evapotranspiration"; Irrigation and Drainage Paper, No. 56, p. 48, FAO Water Resources, Development and Management Service, Rome, Italy.

25 RayyanAzam Khan, Liaquat Ali Khan*, Syed ZahidHussain (2015) Design and Simulation of 0.75hp Soft Start AC Water

Pump Powered by PV Solar System Universal Journal of Mechanical Engineering

26 Said, M.M., Jabori, M.G. (1989). Optimal solar array configuration and DC motor tile

27 parameters for maximum annual output mechanical energy. *IEEE Transactions onEnergy Conversion*. 4(3): 459 – 465.

28 Singer, S., Appelbaum, J. (1993). Starting characteristics of DC motor powered bysolar cells. *IEEE Transactions on EnergyConversion*. 8(1): 47 – 53.

29 Tomas, M. (1998). *Solar electricity*. JohnWiley and Sons Ltd, West Sussex. England

Reference to this paper should be made as follows: Abubakar Jibrin Abdullahi et al. (2019). Overview of the Design and Simulation of Solar Powered Water pumps for Boreholes. *J. of Engineering and Applied Scientific Research*, Vol. 11, No. 1, Pp. 1-15