ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 5, May 2015

Design and Implementation of Automatic Water Spraying Technique over Photovoltaic Cells

D.Baskar, Gopikrishnan M, Dr. P. Radhakrishnan

Assistant Professor, Dept of EEE, Bharath University, Chennai, Tamil Nadu, India

Assistant Professor, Dept of EEE, Bharath University, Chennai, Tamil Nadu, India

Associate Professor, Dept. of EEE, Bharath University, Chennai, Tamil Nadu, India

ABSTRACT: Photovoltaic cells are the heart of photovoltaic water pumping systems. The photovoltaic cells will exhibit long-term degradation if the temperature exceeds a certain limit. In order to utilize PV power properly and increase photovoltaic water pumping system efficiency, it is necessary to keep PV cell temperature and cell reflection as low as possible. The purpose of this paper is to improve the performance of a photovoltaic water pumping system. This is performed by spraying water over the photovoltaic cells. The temperature of the PV cell is measured and if the temperature exceeds certain limit, water is sprayed over the cells automatically, for which a solenoid valve and microcontroller unit is used. The results are compared with traditional systems. Experimental results show that the cells power is increased due to spraying water over the photovoltaic cells. This can significantly increase the system and subsystem efficiency and the pump flow rate. Measurements of the short circuit current of the module, which is nearly temperature-independent, indicated that the water spray improved the system optical performance.

KEYWORDS: Photovoltaic panel, Pumping System, temperature sensor, water spraying.

I. INTRODUCTION

Devices powered by alternative energy sources, such as water pumps, are common in areas where grid power is unavailable and either wind or solar energy is plentiful. The use of photovoltaics for water pumping is appropriate as there is often a natural relationship between the availabilty of solar energy and the water requirement. The water requirement increases during hot weather periods when the radiation levels are highest and the output of the solar array is at a maximum.[1] Utilities are finding it more economical to use a photovoltaic-powered pump than to provide and maintain a distribution line to a remote pump. The cost of photovoltaic installations is mostly dependent on the PV array area. The major disadvantages of using PV are the high installation costs and its low energy conversion efficiency.[2] An increase in system efficiency would obviously reduce the size and cost of the PV array required to pump a given daily volume of water.

It is well known that the efficiency of photovoltaic solar cells decreases with an increase in temperature. This decrease, is resulted first of all in dropping of open circuit cell voltage. The cost of photovoltaic installations is mostly dependent on the PV array area. Therefore, in order to improve the cost effectiveness of PV array powered systems, electric power generated by the PV array should be efficiently utilized. Photovoltaic (PV) water pumping is one the most typical PV applications in developing countries and has the potential to become a major criterion for social and economic development. Photovoltaic cells are the main part of PVPS so that any changes in the cell's power will affect the PVPS performance. Keeping PVPS at high efficiency is the most important designer's goal.[3] Many researchers have investigated and proposed different methods for designing and optimizing the PVPS to improve the system efficiency and reduce the installation costs. Since efficiency and electrical yield decrease with increasing operating temperatures and cell's reflection loss, it is desired to maintain the cell's temperature and cell's reflection as low as

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 5, May 2015

possible. The goal of this work is to investigate the effect of spraying water over the photovoltaic cells on decreasing cell's temperature and cell's reflection. [4]

II. CHARACTERISTICS OF A SOLAR CELL

The usable voltage from solar cells depends on the semiconductor material. In silicon it amounts to approximately 0.5 V. Terminal voltage is only weakly dependent on light radiation, while the current intensity increases with higher luminosity. A 100 cm² silicon cell, for example, reaches a maximum current intensity of approximately 2 A when radiated by 1000 W/m². The output (product of electricity and voltage) of a solar cell is temperature dependent. Higher cell temperatures lead to lower output, and hence to lower efficiency (Fig .1). The level of efficiency indicates how much of the radiated quantity of light is converted into useable electrical energy.[5]

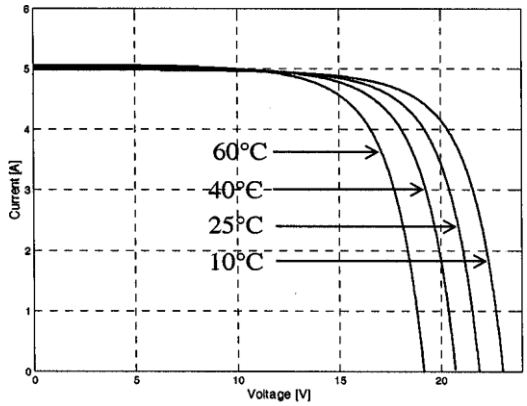

Fig .1. I-V Characteristics at different temperature

III. SYSTEM CONFIGURATION

The experimental facilities consist of 26 PV panels (36×26) and one positive displacement surface water pump with a permanent magnet DC motor. Fig. 3 shows the test setup. The PV panel is of monocrystalline type with 36 cells and fixed at 10˚ facing south. The power produced from the array is transmitted to the DC motor of the pump. Positive displacement pump, (1000 L/h flow rate maximum, 45 m head maximum) is being used to pump water from the tank. [6-8]

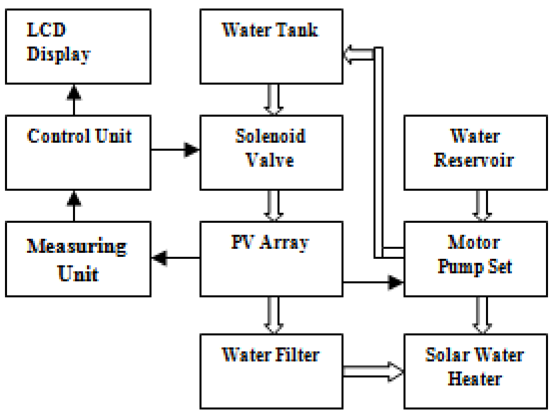

Fig.2. Layout of PVPS with spraying Unit

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 5, May 2015

The water spraying is atomized by control system and spraying unit. The control system includes temperature sensor and microcontroller circuit. The water spraying unit consists of the solenoid valve and water flow pipe. The water required for spraying over the cells is fed by the pump. It is then transmitted over the cells (Fig. 3). Irradiance was measured by a BM 6 Kip & Zonen pyranometer at the same incident plane of the modules.[10]Temperature sensor (LM35) is installed on the back of the a module where the actual temperatures are about 1.5˚C below the temperatures on front of the modules. Wind speed was measured 30cm above the modules. Data were recorded every 10 min.

A .*Temperature measuring and flow control unit*

The temperature of the PV panel increases with the increase in radiation. Temperature sensor LM35 is fixed beyond the PV panel for temperature measurement. The output from the temperature sensor is in millivolts range and hence it is amplified using LM 358 amplifier, before feeding to the microcontroller. PIC 16f877 microcontroller is used for generating the PWM signals in accordance with the variation in temperature of the PV panel.[9]The PWM signal is to drive the MOSFET which acts as a switch between solenoid valve and the power supply.

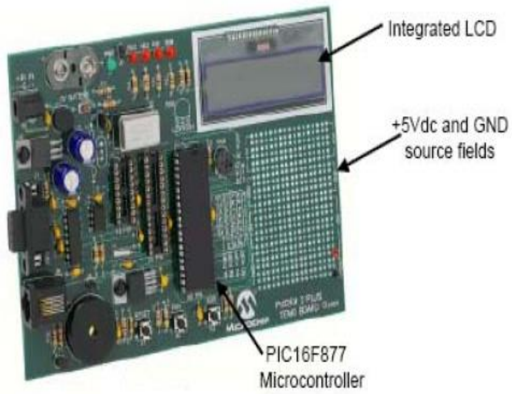

Fig.3. Control system unit

B. Water Spraying Unit

Spraying unit includes the solenoid valve and the pipes with uniform holes for water flow. The solenoid valve is normally closed and opens only when the MOSFET switch closes. The water after flowing over PV cells are collected and fed into solar water heater. Previously water from panel is filtered to purify it.[11]

IV. CELLS TEMPERATURE REDUCTION

The photovoltaic cell efficiency decreases with increasing temperature. The cells will also exhibit long-term degradation if the temperature exceeds a certain limit.[12-13] A crystalline silicon solar cell's electrical power generation depends on its operating temperature. While the short circuit current (Isc) increases slightly with increasing temperature, the open circuit voltage (Voc) decreases significantly (about -2.3 mV/˚C) with increasing temperature. This results in a reduction of electrical power output (and electrical yield) of -0.4%/˚C to –0.5%/˚C for mono- and multi crystalline silicon solar cells, respectively (which are used in most power applications). Since efficiency and electrical yield decrease with increased operating temperatures, it is preferable to keep cells temperature as low as possible. Due to the water spray and additional cooling by evaporation, the cells operating temperatures were significantly reduced in comparison with a module without having water spray which was measured simultaneously.[14]

$$P_{pv} = V_m * I_m \qquad (1)$$

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 5, May 2015

$$\eta_{pv} = \frac{P_{pv}}{GA} \quad (2)$$

$$\eta_{sub} = \frac{P_{hyd}}{P_{PV}} = \frac{\rho g h Q}{P_{PV}} \quad (3)$$

$$\eta_T = \eta_{pv} * \eta_{sub} = \frac{\rho g h Q}{GA} \quad (4)$$

where Ppv is the array power, Im is the maximum PV cell current, Vm is the maximum PV cell voltage, ηpv is the PV cell efficiency, G is the global solar radiation on the tilted PV cell, A is the PV array area, ηsub is the operational subsystem efficiency, ρ is the water density, g is the gravitational acceleration, Q is the pump flow rate, h is the total head and ηT is the total operational system efficiency.[15-20]

V. RESULTS AND DISCUSION

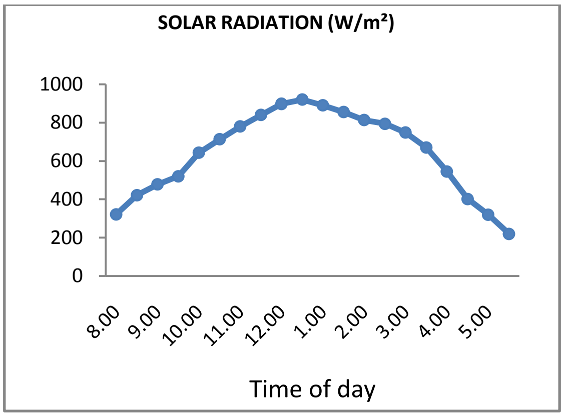

Fig.4. Variation of Solar radiation

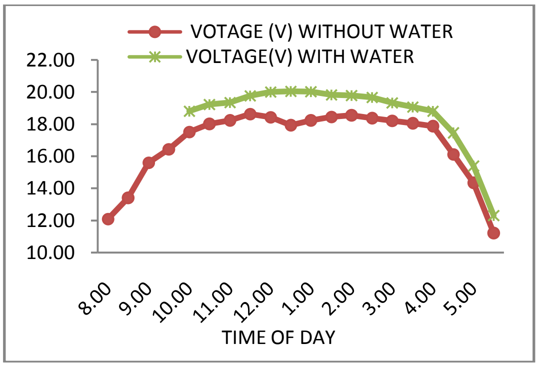

Fig.5.Comparison of voltage with and without spraying water

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 5, May 2015

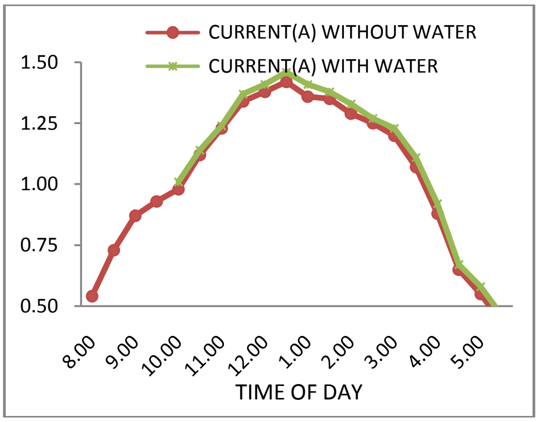

Fig.6. Comparison of current with and without spraying water

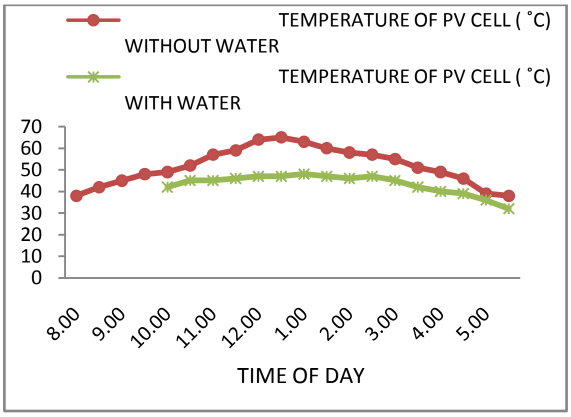

Fig.7. Comparison of cells temperature with and without spraying water

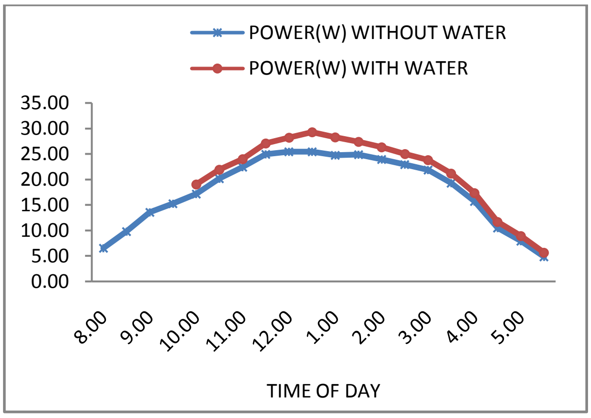

Fig.8.Comparison of power with and without spraying water

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 5, May 2015

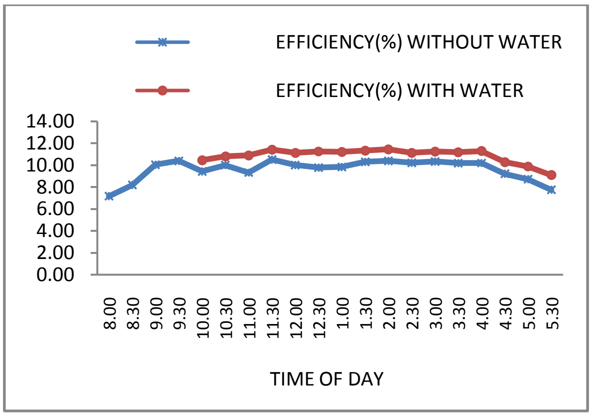

Fig.9.Comparison of efficiency of PV with and without spraying water

Loss of efficiency due to a raised temperature of PV arrays is reduced by heat removal from the front surface by water spray over the cells, which absorbs the heat generated by the cells during the day. This study examines the performance of a 936W photovoltaic water pumping system with water spray over the photovoltaic cells. It is found that spraying water over the photovoltaic cells strongly improves the system and subsystem efficiencies. Since when the modules are working closely at the temperature of maximum power generation, the motor pump can receive most of the cells power. It is shown that, spraying water over the cells increases the mean PV cell efficiency, subsystem efficiency and total efficiency 3.26%, 1.40% and 1.35%, respectively, at 16 m head. Maximum PV cell efficiency at standard condition is 13.5%. The photovoltaic water pumping system with water spray over the cells achieves 12.5% mean PV cell efficiency during the test day. Measurements of the short circuit current of the modules, which is nearly temperature independent, indicated that the water spray improved the optical performance by 1.8%.

VI. CONCLUSION

Numerous ideas to reduce reflection have been proposed, but most have drawbacks: antireflective coatings are not durable and structured surfaces are expensive, accumulate dust and are difficult to clean. Yet water, with a refractive index of 1.3, is a viable intermediary between glass (nglass=1.5) and air (nair=1.0). In addition to help keeping the surface clean, water reduces reflection by 2–3.6%, decreases cell temperatures up to 35^{0}C and the electrical yield can return a surplus of 10.3%; a net gain of 8–9% can be achieved even when accounting for power needed to run the pump.

REFERENCES

Zaki A, Eskander M. Matching of photovoltaic motor-pump systems for maximum efficiency operation. Renewable Energy 1996;7(3):279–88.
[2]Sukumaran V.G., Bharadwaj N., "Ceramics in dental applications", Trends in Biomaterials and Artificial Organs, ISSN : 0971-1198, 20(1) (2006) pp.7-11.
[3]Jafar M. A model for small-scale photovoltaic solar water pumping. Renewable Energy 2000;19:85–90.
[4]Selva Kumar S., Ram Krishna Rao M., Balasubramanian M.P., "Chemopreventive effects of Indigofera aspalathoides on 20-methylcholanthrene induced fibrosarcoma in rats", International Journal of Cancer Research, ISSN : ISSN: 1811-9727, 7(2) (2011) pp.144-151.
[5]Short T, Oldach R. Solar powered water pumps: the past the present and the future? Journal of Solar Energy Engineering 2003;125:76–82.
[6]Menon R., Kiran C.M., "Concomitant presentation of alopecia areata in siblings: A rare occurrence", International Journal of Trichology, ISSN : 0974-7753, 4(2) (2012) pp.86-88.
[7]LangridgeW, LawranceW, Wichert B. Development of a photovoltaic pumping system using a brushless DC motor and helical rotor pump. Solar Energy 1996; 56:151–60.
[8]Rayen R., Hariharan V.S., Elavazhagan N., Kamalendran N., Varadarajan R., "Dental management of hemophiliac child under general anesthesia", Journal of Indian Society of Pedodontics and Preventive Dentistry, ISSN : 0970-4388, 29(1) (2011) pp.74-79.
[9]Kou Q, Klein S, Beckman W. A method for estimating the long term performance of direct-coupled PV pumping systems. Solar Energy 1998;64: 33–40.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 5, May 2015

[10]Shanthi B., Revathy C., Devi A.J.M., Subhashree, "Effect of iron deficiency on glycation of haemoglobin in nondiabetics", Journal of Clinical and Diagnostic Research, ISSN : 0973 - 709X, 7(1) (2013) pp.15-17.

[11]Arab A, Chenlo F, Benghanem M. Loss-of-load probability of photovoltaic water pumping systems. Solar Energy 2004;76:713–23.

[12]Born M, Wolf E. Principles of optics. 5th ed. Oxford: Pergamon; 1975.

[13]Krauter, Hanitsch R. The influence of the capsulation on the efficiency of PV-modules. In: Proceedings of the 1st word renewable energy congress, vol.1. Reading: UK; 1990 September 23–28. p. 141–4.

[14]Krauter S, Hanitsch R, Strauss PH. Simulation-program for selecting efficiency improving strategies of PV-module encapsulations under operating conditions. In: Proceedings of renewable energy sources '91, international conference, vol. 3. Prague: CFSR; 1990 July 1–4. p. 48–53.

[15]Krauter S, Hanitsch R, Campbell P, Wenham SR. Optical modeling, simulation and improvement of PV module encapsulation. In: Proceedings of the 12th European photovoltaic solar energy conference and exhibition, vol. 2.

[16]B.Mehala, Mrs.Anitha Sampath Kumar, Design and Implementation of Resonant Circuit Based On Half-Bridge Boost Rectifier with Output Voltage Balance Control, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, ISSN (Online): 2278 – 8875,pp 9370-9378, Vol. 3, Issue 5, May 2014

[17]B.Vamsi Krishna, Starting Inrush Current Control of Three-Phase Induction Motors for Dispersed Generating Systems, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, ISSN (Online): 2278 – 8875,pp 6411-6422, Vol. 2, Issue 12, December 2013

[18]B.Vamsi Krishna, Significance of TSC on Reactive power Compensation, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, ISSN (Online): 2278 – 8875,pp 7067-7078, Vol. 3, Issue 2, Febuary 2014

[19]RITESH KUMAR JHA1, LINGESWARAN . K, Fault-Tolerant Voltage Source Inverter for Permanent Magnet synchronous motor, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, ISSN: 2231-5381,pp 23-27, Volume 3 Issue 2 No 4 – April 2012

[20]Ramamoorthy.S, Power Quality Issues Of Distributed Generation in distribution Network and its impact on system Power Loss and voltage profile, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, ISSN (Online): 2278 – 8875,pp 11751-11764, Vol. 3, Issue 9, September 2014