

Single Sensor Based Photovoltaic Maximum Power Point Tracking Technique for Solar Water Pumping System

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Summary: The development of photovoltaic (PV) panels has made solar-powered pumps a reality. The pump drivers are usually direct-current (DC) motors which are fed by power electronic converters with maximum power point tracking (MPPT) to extract the whole energy that the PV panels can generate depending on the environmental conditions including irradiation and temperature. The implementation of MPPT algorithm essentially involves sensing both an input current and an input voltage. Understandably, such realization is expensive. In this paper, a solar PV water pumping system based on DC to DC converter as MPPT module is considered. The system consists of a PV array, a DC to DC boost converter and the DC motor coupled to a centrifugal pump. A proposed method is employed to seek the maximum power point using the flow rate obtained from a single sensor. A comparison with conventional hill climbing technique is included in experimental results to prove feasibility of the proposed method.

Key words:

*MPPT,
Boost converter,
microcontroller,
DC motor-pump,
Flow rate*

1. INTRODUCTION

Water pumping system has a long history; so many methods have been developed to pump water with a minimum of effort. These have utilized a variety of power sources, namely human energy, animal power, hydraulic power, wind, solar and fossil fuels for small generators. Solar PV water pumping has been implemented around the globe as an alternative electric energy source for remote locations since solar PV was invented. The solar PV systems are cost effective in many remote applications such as water pumping for households, live stock and wildlife, space heating, lighting remote vacation homes and emergency traffic applications [4]. The PV systems involve the direct conversion of sunlight into electricity with no intervening heat engine. PV devices are solid state; therefore, they are rugged and simple in design and require very little maintenance.

The MPPT is a sub-system designed to extract the maximum power from a power source. In the case of solar panels power source, the maximum power point varies as a result of changes in its electrical characteristics which in turn are functions of radiation dose, temperature, ageing and other effects. The MPPT maximizes the power output from panels for a given set of conditions by detecting the best working point of the power characteristic and then controls the current through the panels or the voltage across them.

Many MPPT methods have been reported in literature. These methods of MPPT can be classified into three main categories that include; lookup table methods, hill climbing methods and computational methods. The methods vary according to the degree of sophistication, processing time and memory requirements [2].

A single sensor MPPT control method for a solar PV water pumping system is investigated in this work. This control method offers advantages of the simplified hardware configuration and low cost by using only one sensor to

measure the flow rate. This latter information is used by an MPPT algorithm to maximize the power drawn from the PV array. The proposed method is compared to conventional hill climbing technique and implemented by a low cost 8-bit RISC microcontroller (PIC16f877A) to control the duty cycle of DC to DC boost converter with pulse width modulation (PWM) in a solar PV water pumping system including a PV array, DC motor-pump and water storage tank with pipes.

2. PV ARRAY AND DC PUMP CHARACTERISTICS

The PV solar array generates electrical power as a direct current. The produced power varies with amount of sun shining on the array and temperature. If this latter held constant, this power variation results in a variable current at a fixed voltage. Increasing (decreasing) temperature reduces (increases) PV array's output power.

The used PV array consists of two parallel connected sets of 10 modules each. The modules are of the type LA361K51 (SI-polycrystalline, Kyocera manufacturer) with typical peak power 51 Wp. The current-voltage relationship of the PV array is shown by the I-V characteristic for different irradiation levels in Figure 1.

The DC motor-pump comprises a surface centrifugal water pump (Electropompe CM100) coupled to permanent magnet DC motor (Nominal Voltage: 180V, Nominal current: 4,9A input Power: 1 HP, Leroy Somer manufacturer). The below Figure shows DC pump behaviour superimposed on I-V characteristic. At any time, the operating point is the intersection of the two characteristics. At different irradiance levels and constant temperature, the intersection points are far from the MPP. To overcome this problem, a MPPT module can be used to maintain the PV array's operating point at MPP.

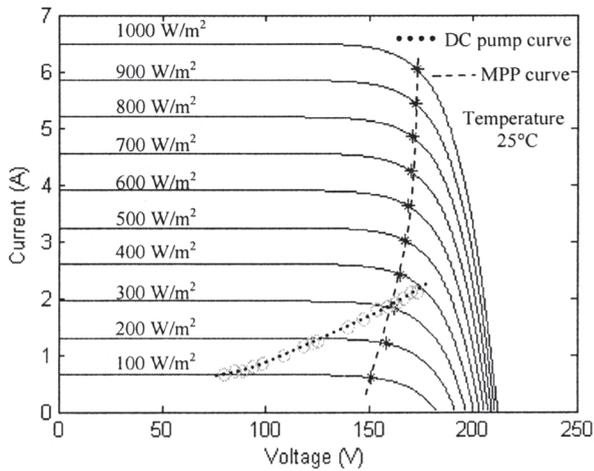


Fig. 1. DC motor-pump I-V curve on PV I-V curves for varying irradiation

3. MPPT ALGORITHMS

3.1. Hill climbing method

As the name of the hill climbing method states, this process works by increasing or decreasing the duty cycle of a buck or boost DC to DC converter and observing its impact on the array output power. This latter is compared to its previous value and according to the result of the comparison, the sign of “slope”, which is a program variable ($\text{slope} \in \{1, -1\}$), is either complemented or remains unchanged [3]. Then, the PWM output duty cycle is changed accordingly. Figure 2 shows the flowchart diagram of hill climbing method as it is implemented in controlling microcontroller.

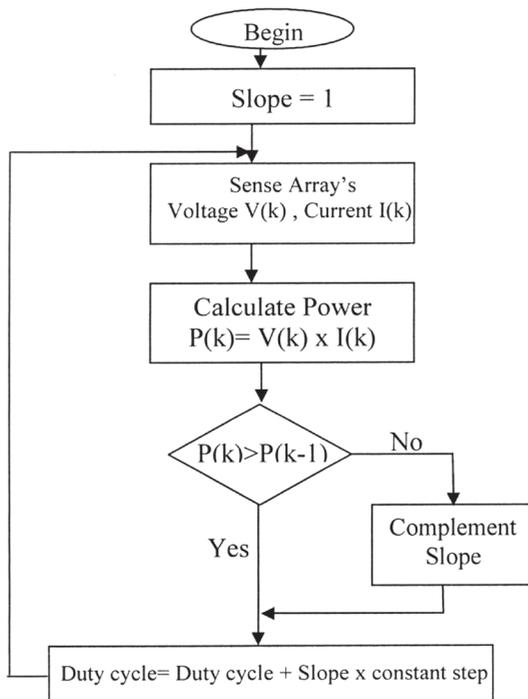


Fig. 2. Flow chart of the hill climbing technique

3.2. Proposed MPPT method

This method has simple feedback structure by using only one sensor to extract the maximum power from a PV array. It operates by periodically incrementing or decrementing the duty cycle of a DC to DC converter and comparing the present flow rate (FL (k)) value with the previous measurement (Fig. 3). If the duty cycle changing leads to an increase (decrease) in flow rate value, which means an increase (decrease) in array’s power, the subsequent changing is made in the same (opposite) direction. In this manner, maximizing flow rate leads to maximizing PV array’s output power under different irradiation conditions.

4. SYSTEM DESCRIPTION

A detailed block diagram of the proposed system is shown in Figure 4. A DC to DC boost converter is used to interface the PV array output to DC motor driven centrifugal pump. The control unit consists of a microchip PIC16F877A-I/P microcontroller and interface circuits required to lead the PV array’s voltage and current signals to the microcontroller. A turbine flow rate sensor (Type DF-HN, 120 l/min H₂O, KOBOLD) is used to provide an indirect measurement of the flow rate velocity in l/min with a square wave signal as an output signal whose frequency varies linearly with flow rate. The latter output waveform is shaped by hex Schmitt-trigger inverter chip (74LS14N) and applied to microcontroller 16-bit timer/counter pin (T1CKI).

The controller on chip 10-bit Pulse Width Modulation (PWM) generator output drives the DC to DC boost converter according to MPPTs algorithms. The boost converter comprises: MOSFET switch IRF730, diode BYT 71 and coil (L = 1mH) [4]. The switching frequency (6,125 KHz) is designed to obtain low output ripple. To implement the serial communication with the PC which has a display

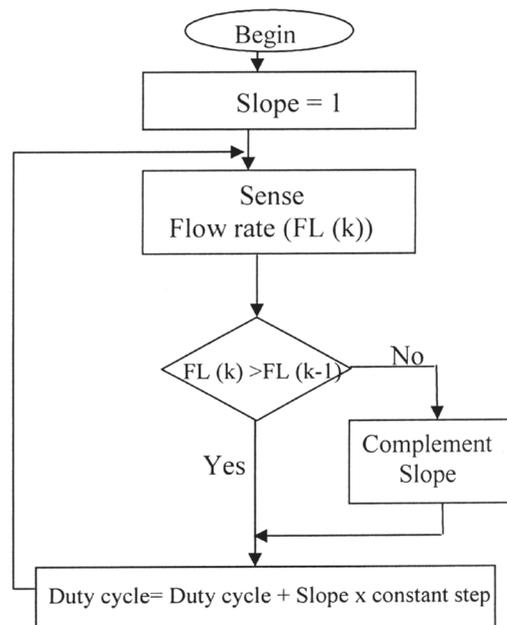


Fig. 3. Flow chart of the proposed method

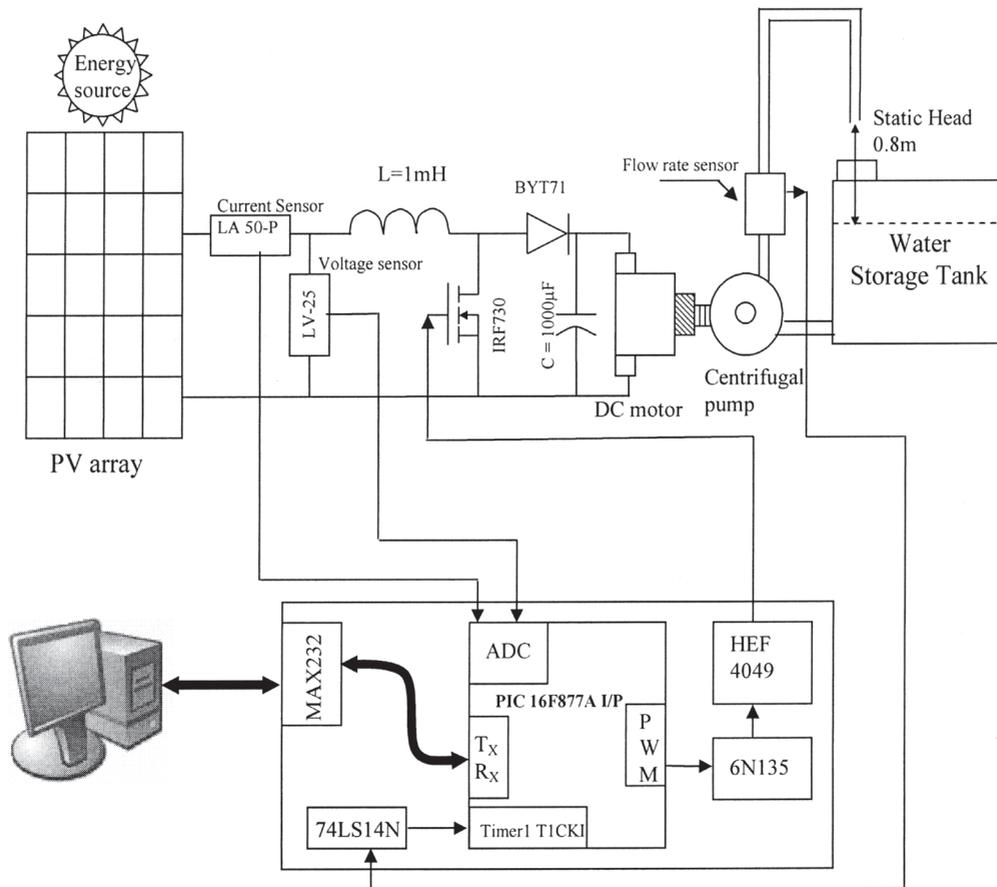


Fig. 4. Block diagram of experimental setup

program of the PV array's output power and flow rate, the only component needed is a line driver and receiver chip (MAX232).

5- EXPERIMENTAL RESULTS

The test of MPPT algorithms was conducted on partially clear sky (Average irradiance 556w/m^2 , average temperature: 32.9°C) and the power source was the PV array ($V_{OC} = 212\text{V}$, $I_{SC} = 6,5\text{A}$). According to the voltage and current of the PV array or flow rate, the microcontroller computes the output and generates a command representing the duty cycle given by the microcontroller PWM pin which is applied to the MOSFET driver, amplified and injected between gate terminal and source terminal of the N-channel MOSFET. The converter duty cycle is adjusted such that maximum PV array output power is extracted under all operating conditions and transferred to DC motor-pump which in turn draws water from a storage tank in a closed hydraulic system.

Figures 5,7 and 9 show PV array output power obtained by application of the proposed method, the hill climbing technique and the direct coupling between PV array and DC motor-pump respectively. As can be seen from Figures 5,7 and 9, the MPPT controller based on the proposed method successfully reached the maximum power point with fast convergence and this can be confirmed by figures 6,8 and Figure 6. PV array output power obtained by application of the proposed method 10 showing the flow rate for each technique.

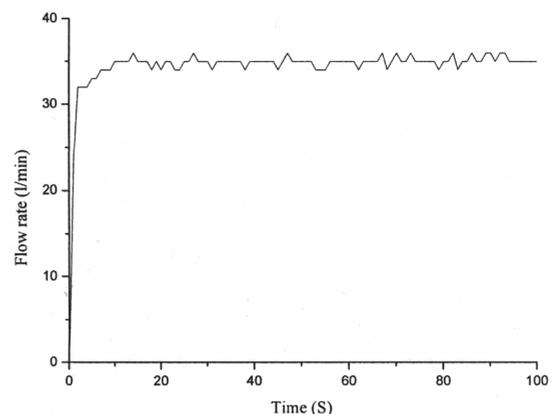


Fig. 5. The flow rate obtained by application of the proposed method

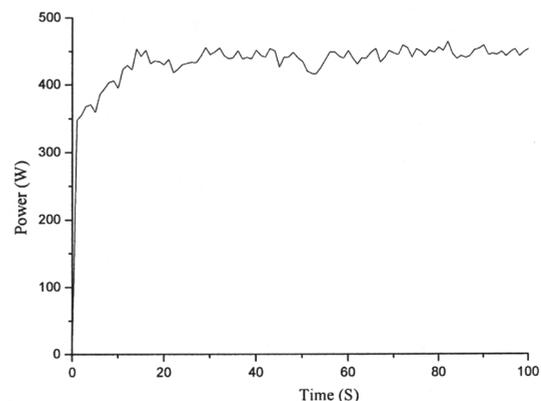


Fig. 6. PV array output power obtained by application of the proposed method

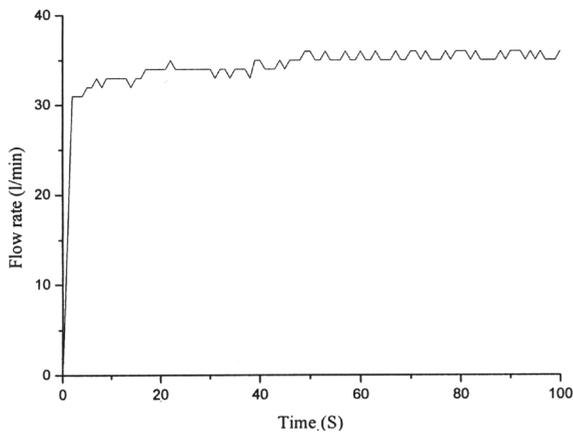


Fig. 7. The flow rate obtained by application of the hill climbing technique

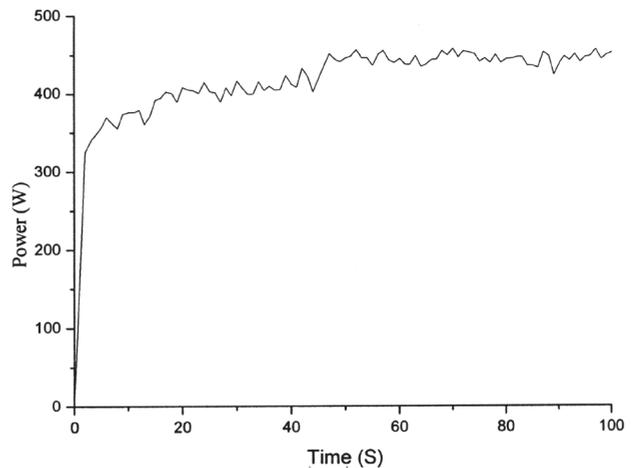


Fig. 8. PV array output power obtained by application of the hill climbing technique

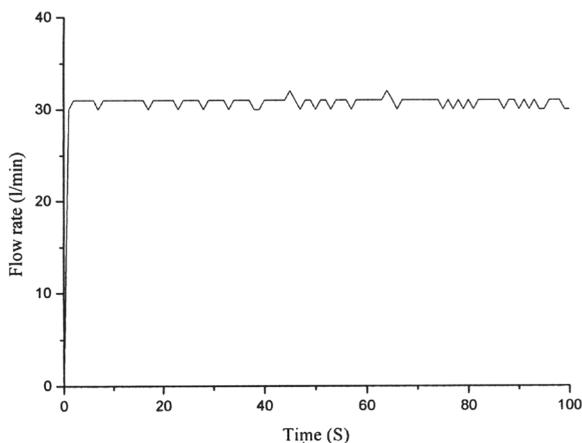


Fig. 9. The direct coupled PV water pumping system flow rate

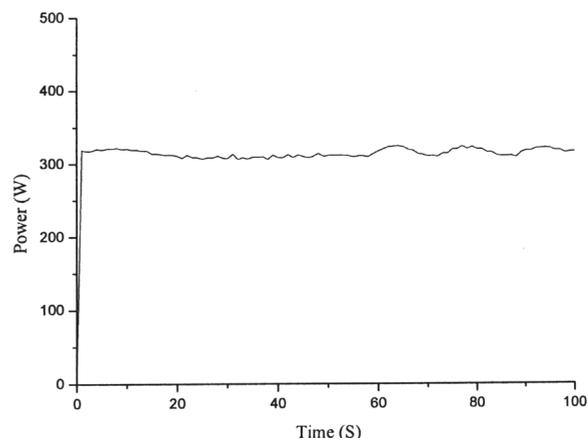


Fig. 10. PV array output power for direct coupled PV water pumping system

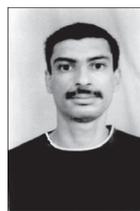
6. CONCLUSION

In this paper, a MPPT technique for solar PV water pumping system using single flow rate sensor has been developed. Solar energy is captured by a PV array and delivered into a DC motor-pump through a DC to DC boost converter which performs the function of tracking the MPP. The system is controlled by a RISC microcontroller based on a flow rate sensor to draw the maximum available power that the PV array can generate under all operating conditions. The comparison with conventional hill climbing technique has shown that the proposed method offers advantages of simplified hardware configuration, low cost and fast convergence to reach the MPP.

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