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PERFORMANCE EVALUATION OF 1.68 kWp DC OPERATED SOLAR PUMP WITH AUTO TRACKER USING MICROCONTROLLER BASED DATA ACQUISITION SYSTEM

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ABSTRACT

The widespread application of Renewable Energy Sources (RES) requires the use of data acquisition units both for monitoring system operation and control of its operation. In this paper, the developed Data Acquisition System (DAS) for applications of remote system monitoring and performance evaluation is presented. DAS is an imported technology for most developing countries like Bangladesh, meaning high cost and a barrier to the dissemination of such systems. The design and implementation of a low cost DAS is motivated by the need to offer an alternative for commercial systems, which are more expensive, usually imported and have proprietary software. In addition, commercial DASs do not allow amendments and adjustments to hardware nor software. A 1.68 kWp solar power driven submersible multistage centrifugal pump with single axis auto tracker has been installed at Head Office (HO) Building of the Bangladesh Atomic Energy Commission (BAEC) premises, Agargaon, Dhaka to meet the daily consumption of about 15,000 liters of water. The objective of this paper is to evaluate the performances of 1.68 kWp solar pump with auto tracker system using microcontroller based low cost universal DAS. In order to evaluate the actual discharge capacity with respect to designed capacity under local solar irradiance and photovoltaic array power output, it is not convenient to gather years' data manually. The developed DAS is used to collect data every minute and to store the average of this data. In order to verify its performances, discharge capacity and efficiency of the pump with respect to time is evaluated from the collected data using the DAS.

Keywords: Data Acquisition System (DAS), Solar Pump, Auto Tracker, Performance Monitoring.

1. INTRODUCTION

The objective of this research paper is to develop a low cost universal DAS applied to a decentralized renewable energy (RE) plant for monitoring parameters and system efficiency with USB interface. The system consists of a set of transducers for measuring both non-electrical (e.g. discharge, solar irradiation etc.) and electrical parameters (photovoltaic array voltage and current, power etc.). An A/D converter interfaced to a microcontroller-based unit records sensors' signals, while the collected data are first conditioned using precision electronic circuits, stored in an external EEPROM and then interfaced to a PC using a data-acquisition module, where they are stored for further processing. A program developed using Graphical User Interface (GUI) is used to further process, display and store the collected data in the PC disk. The developed DAS is configured to perform all readings every minute and store the average of this data in the external EEPROM every 10 minutes and then transmit it to PC data logger. From this data, real time discharge vs. Time and Efficiency vs. Power Output Characteristic graph can be constructed. This method has the advantages of rapid data-acquisition system development and flexibility in the case of changes, while it can be easily extended to control the RES system operation by some essential hardware modifications. To ensure the low cost of the DAS and to promote the dissemination of this technology in developing countries, the proposed data acquisition firmware and the software for USB microcontrollers programming is a free and open source software, executable in the Linux and Windows® operating systems [1-8].

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2. METHODOLOGY

In this section, the design of a data acquisition system (data logger) and its various existing techniques for remote data transmission are described. Five parameters are needed for complete evaluation of performance of solar water pumping system such as solar irradiance, water flow rate, PV panel voltage, PV panel current and surrounding temperature. The data are first collected, conditioned using precision electronic circuits and then transmitted to a personal computer (PC). The information from the data logger can be transmitted via direct connections such as USB, RS232, RS485 to a PC, where they are processed using the appropriate data acquisition software. Suitable software is then used to further process, display and store the collected data on PC. Figure 1 shows the schematic diagram of an existing system design.

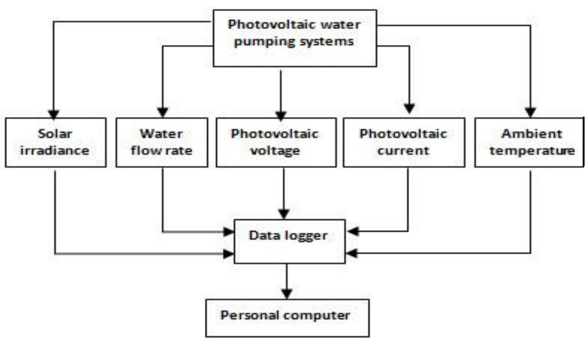

Fig 1. Data from the PV water pumping station to the personal computer

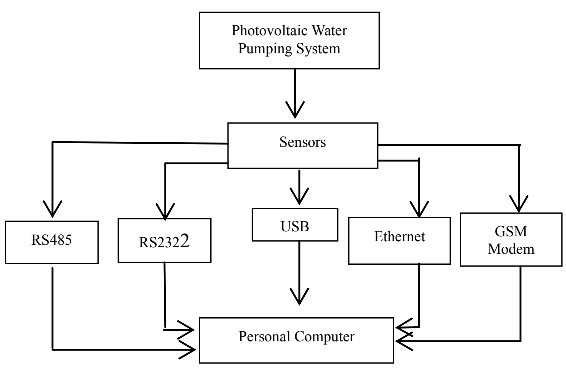

Fig 2. Field data transmission possibilities

Figure 2 shows a general scheme of the various possibilities for field data collection and its transmission to a PC.

3. DEVELOPED DATA ACQUISITION SYSTEM

3.1 Description of the Developed Data Logger

In this section a description of the field data-acquisition system is developed to collect and transmit the information from the sensors down to the PC. The collected data are first conditioned using precision electronic circuits based on the ATmega32 microcontroller and then interfaced to a PC using an RS232 connection. Figure 3 presents a schematic of the system design.

The information from the sensors goes to the microcontroller, where it is processed and passed to the external 24C32A EEPROM memory and later to PC via the RS 232 interface [9-10]. The treated data are converted into their real physical values (current, voltage, irradiation, etc.) and used to analyze the performance of the considered photovoltaic water pumping systems.

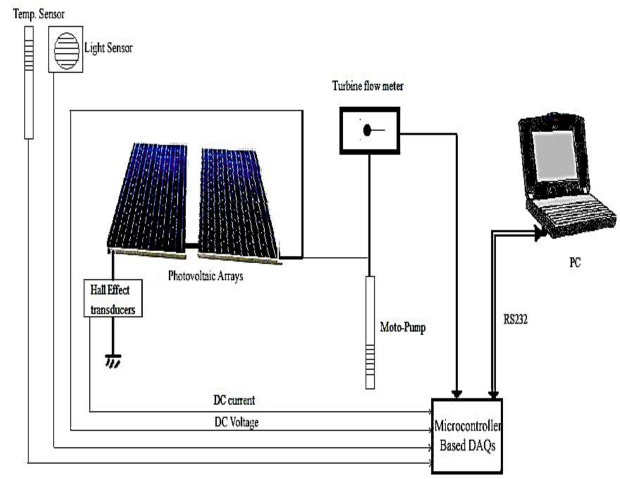

Fig 3. Schematic of system design

The block diagram of the interface circuit consists of two sub-circuits: the data acquisition section and the serial communication part. Figures 4-6 present the scheme of the electronic circuits of the data acquisition section. Figure 7 presents the scheme of the serial communication part on the ISIS program.

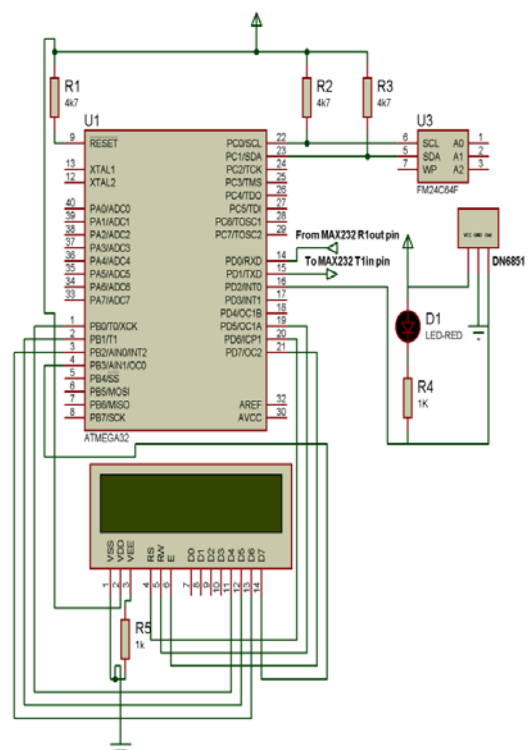

Fig 4. Data acquisition circuit of flow meter

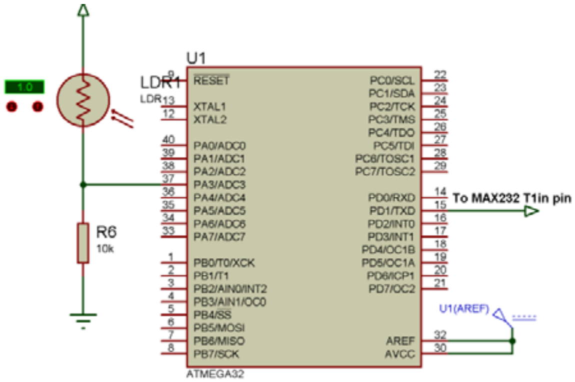

Fig 5: Data acquisition circuit of light meter

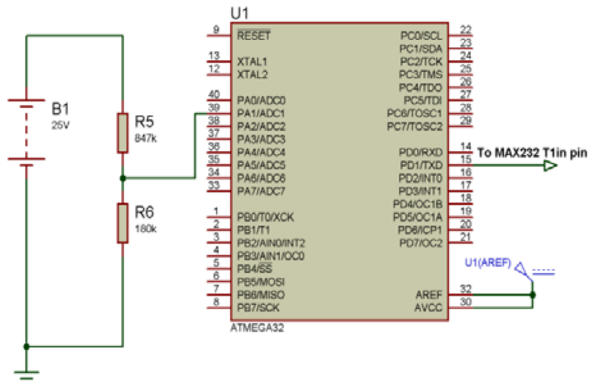

Fig 6. Data acquisition circuit of wattmeter

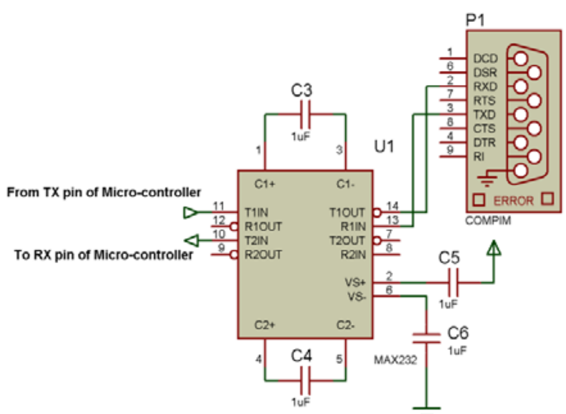

Fig 7. Circuit for data transmission to PC

The interface is based on an 8-bit microcontroller (the ATmega32) operating at 1 MHz, which handles all the different processes through the corresponding software. The ATmega32 microcontroller was specifically selected for this project in order to produce a fast and low cost prototype. The microcontroller includes 32 KB of internal flash memory, together with a large RAM area and an internal EEPROM and three timers (one 16-bit timer with two 8-bit timers). An 8-channel 10-bit A/D converter is also included within the microcontroller, making it ideal for real-time systems, and monitoring applications. All port connectors are brought out to standard headers for easy connection and disconnection.

The external 24C32A EEPROM memory is a 4 K × 8 (32 K bit) Serial Electrically Erasable PROM. It has been developed for advanced, low power applications such as personal communications or data acquisition. The 24C32A also has a page-write capability of up to 32 bytes of data. It is capable of both random and sequential reads up to the 32 K boundary. Functional address lines allow up to eight 24C32A devices on the same bus, for up to 256 K bits address space.

The ATmega32 is programmed using C language. The visualization of the data acquisition system results on the computer requires the implementation of a graphic interface. The desktop application was developed using Visual Studio 2010. It has a communication control that provides access to the serial port for communication purposes. The desktop application is used to further process, display and store the collected data on the PC's disk [11-13]. Figure 8 shows the interface of the data acquisition software.

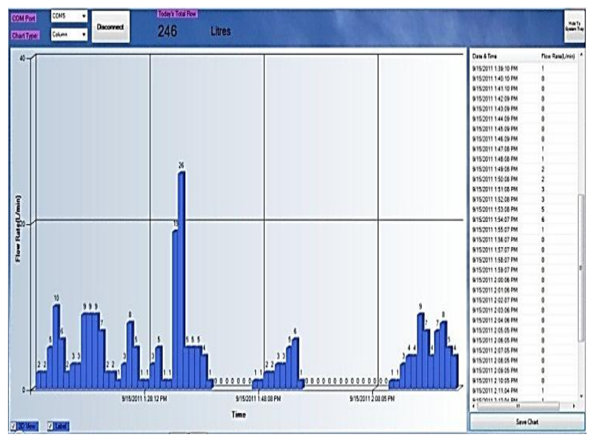

Fig 8. Interface of the data acquisition software

3.2 The Sensors and Interface Circuits

The sensors provide the measurement interface between the sensor systems, using the variations in physical phenomena to measure analog parameters. All analog signals are sampled sequentially and the input voltage data are calibrated to correspond to actual physical units. The calibration equations have the general form:

$$y_i = a_i x_i + b_i \qquad (1)$$

Where y_i is the i-th sensor output in physical units, x_i is the i-th sample and a_i, b_i are calibration constants. The proposed system consists of a set of sensors (it can record up to three different sensors) for measuring both meteorological (e.g., solar irradiance, temperature, etc.) and photovoltaic parameters (water flow rate, photovoltaic voltage, current, etc.).

The global solar radiation on an inclined and horizontal surface are the principal measured parameter, while pumped water flow rate, the ambient temperature, voltage and current of photovoltaic field (*V*, *I*) are also measured in order to construct a complete data base of the site and the system. A turbine flow meter has been used for the flow rate measurements. The flow meter works in the 0-10 m^3/h range with an accuracy of ±0.05%. The flow meters give a 4:20 mA analog signal calibrated to the measured flow rate. A solar cell has been used to measure the global solar radiation in the horizontal plane and in the plane of the PV arrays. Ambient temperature has been measured using an LM 35 sensor shielded from the Sun. The DC voltage and current generated by the PV arrays and the AC voltage and current drawn by the pump motors have been measured using Hall Effect transducers of appropriate ranges.

4. DESCRIPTION OF THE PV WATER PUMPING SYSTEM

In this work, the solar water pumping station, which was selected as the case study is named as 1.68 kWp Solar Pumping Plant located at HO Building of Bangladesh Atomic Energy Commission, Agargaon, Dhaka. The system is used for pumping water at the height of 27m (7 storied building) from the underground reservoir. A PV water pumping system (PVWPS) consists of a PV array, inverter, submersible pump, storage tank, and an auxiliary system of measuring devices and weather monitoring sensors as shown in Fig.3; the station works without storage batteries.

Major components of the system include:
(a) Solar PV Module;
Total installed capacity: 1.68 kWp
Module quantity: 14 Nos.
Module type: Monocrystalline, Each 120 Wp@12V
Module efficiency: 14 -15%
(b) Submersible DC motor-pump;
Power of the motor: 1.68 kW
Pump efficiency: 92%
Discharge capacity: 40,000 Liters/day (max^m)

5. RESULTS AND DISCUSSIONS

The experimental data recorded in the data logger at one hour time interval and then transmitted from the photovoltaic water pumping systems to the PC via the USB located at HO Building of Bangladesh Atomic Energy Commission, Agargaon, were analyzed. Table 1 shows the data obtained from the PV water pumping system for two days during the month of Sept. 2011.

Table 1: Solar intensity and flow rate on 28-29 Sept. 11

Day	Time	Solar Intensity		Flow Meter Reading (L/hr)	Total Volume Discharged (Liters)
		(lux)	(W/m2)		
28-10-2011	10:00:00 AM	78000	616.2	652	4561
	11:00:00 AM	82000	647.8	690	
	12:00:00 PM	87000	687.3	780	
	1:00:00 PM	98000	774.2	867	
	2:00:00 PM	72000	568.8	643	
	3:00:00 PM	56000	442.4	463	
	4:00:00 PM	42000	331.8	276	
	5:00:00 PM	36000	284.4	190	
29-10-2011	10:00:00 AM	78000	616.2	752	5072
	11:00:00 AM	84000	663.6	788	
	12:00:00 PM	95000	750.5	660	
	1:00:00 PM	102000	805.8	990	
	2:00:00 PM	88000	695.2	649	
	3:00:00 PM	69000	545.1	588	
	4:00:00 PM	52000	410.8	405	
	5:00:00 PM	40000	316	240	

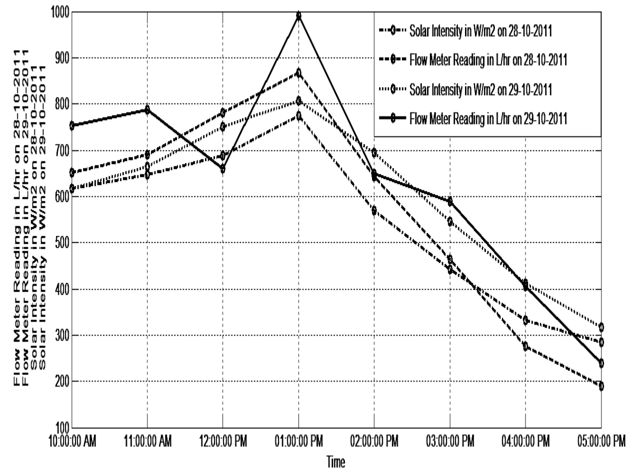

Fig 9. Variation in solar intensity and flow rate on 28-29 Sept., 11

There is no direct conversion between lux and W/m^2; it depends on the wavelength or color of the light. However, for sunlight, there is an approximate conversion of 0.0079 W/m^2 per Lux.
The pump output is measured using the Eq. (2).

$$\text{Pump Output, } P_o = \rho QH \quad (2)$$

Where,
ρ = Specific weight of water = 9810 N/m^3
Q = Volumetric flow rate in m^3/s
H = Static head = 30.48 meters

From Figure 9, it can be seen that the light intensity is maximum at approximately 11 am to 2 pm. The overall efficiency of the panel is also highest during this time. The average daily quantity water pumped by the station is around 10 m^3/day. From figure 9, it can be found that the maximum mean flow rate occurs at midday in summer with 20 m^3/day.

6. CONCLUSION

The use of low cost DAS facilitates the spread of the measurements in RE plants, thus allowing recognized local energy resources such as solar radiation and wind speed to monitor the power conversion efficiency and to analyze the financial advantage of using such plants. Since the financial resources of developing countries are limited, cost-effective solutions are welcome to contribute to a decentralized power generation policy. The developed architecture has the advantages of rapid development and flexibility in the case of changes, while it can be easily extended for controlling the RE system operation. Another advantage of the developed DAS, besides the efficiency and reliability, is the financial factor, due to the use of low cost and easy availability of components in the local market. Finally, the developed DAS works successfully and shows good performances, sensitivity, reliability and easy programming in both Linux and Windows® operating systems.

7. REFERENCES

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