Solar Powered, Controlled Irrigation System at the UDC Experimental Farm

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ABSTRACT: The work describes a solar powered, micro-controlled irrigation system implemented at the University of the District of Columbia's Experimental Farm. The goal of the project is to design a smart irrigation system powered by a sun-tracking solar power system. The system is tailored to the type of food crop being grown. It uses an automatic irrigation system which incorporates the theory of digital control and feedback. This helps reduce the problems associated with water waste in farming. It also increases food crop production. The project has a water level control system and a water distribution system. The water level in the tank is controlled by a float switch. The float switch will maintain the water tank full at all time and uses a well as a source of water. If the water supply in the well is insufficient, a service line is used as an alternative and for demonstration purpose. The water distribution system is composed of a microcontroller, various wireless moisture sensors, a solenoid valve and the irrigation pipes. A moisture sensor sends information about the soil humidity level to the microcontroller. The distribution pipe is connected to a solenoid valve. When the moisture of the soil is below desired level, the solenoid valve is switched on to initiate irrigation of the selected area. There is scheduled irrigation duration for each area based on the crop type. The system is proposed to be a model for a self-powered, standalone small scale irrigation system, ideal for semi-rural farming.

Keywords: Stand-alone PV systems, Water Pumping

1 INTRODUCTION

Scarcety of freshwater resources worldwide, coupled wih world population growth and increased food demand, are major challenges facing our society. There is an urgent need to create strategies based on science and technology for sustainable use of water, including technical, agronomic, managerial, and institutional improvements. The University of DC, which is a land grant institution, has a research farm, located in the suburb of Waashington, DC, the Muirkirk Farm [1] in Beltsville, Maryland, which serves as a research site for some of the Agricultural Experiment Station projects, undertaken by the College of Architecture, Urban Sustainability and Environmental Sciences (CAUSES), jointly with the School of Engineering and Applied Science of the University. The farm site has greenhouses, crops and a couple of office administration. The current project described in this paper provides a self powered "smart" irrigation system using groundwater from a well. The objective of this project is to develop a system that will minimize the waste of water and use the exact water required by a given crop and the moisture of the soil. The project allows to collect data from a humidity, temperature and flow sensor, and soil moisture sensor which will be sent wirelessly to the cloud. The syetm can be accessed and monitored from the cloud on a dedicated website.

2 INITIAL PREPARATIONANS

2.1 Solar power

The power requirements of the installation of the project are the following:

- Submersible pump operation:
  30-300 VDC or AC, PE. (900W);
- Solar tracker PV module operation:
  120W, 24VDC solar tracker motors;
- Microprocessor and other miscellaneous:1W;
- Water Flow controller: 12-40V DC/AC, 120W; and
- Solenoid Valve: 24 VAC 50/60 Hz

The estimated power requirement for a totally self-dependent system is lower than 2000W.

The proposed power delivery system is a solar tracking photovoltaic system as depicted in Fig. 1.

The galvanized steel-pole mounted two-axis solar tracking PV system is the central power source which converts solar energy into a 2KW DC electrical power. The DC power is then converted to AC through a 2.4KW, 115V, 60Hz inverter and provides adequate power to the system. In addition, various voltages are derived from the inverter to provide smaller AC voltages (i.e 24V) through step-down power transformers.

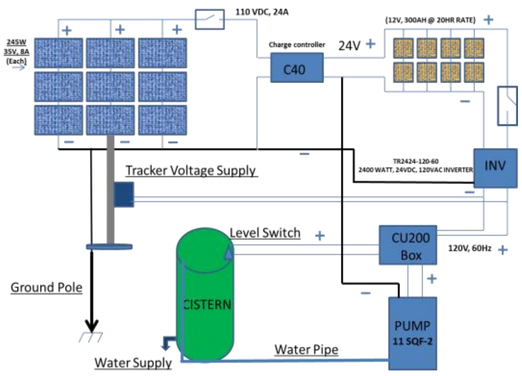


Figure 1: Solar tracking PV power system

2.2 Underground water

Initially, underground water availability was assessed by hydro geologists and a 90-ft bore hole was drilled at an appropriately selected, elevated location and a sizeable aquifer was secured. A submersible pump capable of a flow of 10 USGPM was lowered in the borehole and connected to a 5000-gallon cistern for storing the ground water to be used for irrigation.

3 SMART IRRIGATION SYSTEM DESIGN

3.1 Basic layout

The proposed automatic irrigation system, powered with solar energy, allows the collection of a number of different readings from a set of sensors scattered in the soil of a selected lot of land. These sensors sense the soil temperature and humidity level and evaluate its moisture.

The collected data is then wirelessly transmitted to a hub which will process the data and send appropriate electrical control signals for operating a solenoid valve which in turn controls the water flow for irrigation of a selected crop.

3.2 The sensor node

The sensor node, depicted in Fig. 2, consists of the following components:

- Arduino UNO microprocessor
- XBee Series 1 Shield
- SHT1 moisture sensor
- 6V DC Solar Panel
- Tenergy 9V, 250mAh NiMH, high capacity rechargeable Battery

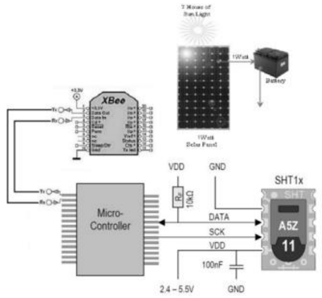


Figure 2: Diagram of the sensor node

The sensor is locally powered with a mini solar panel which recharges a 250mAh battery. The power generated by the solar panel is adequate to supply power to the Arduino UNO microprocessor and to the moisture sensor device.

The main function of the sensor node is to:

- Collect the soil Temperature (T), Relative Humidity (RH) an Dew Point (Td); and
- Send data wirelessly to HUB (ZigBee protocol)

The moisture sensor is interfaced with a low cost, very popular microprocessor, the Arduino UNO. The temperature and humidity values are sensed with a built-in transducer of the moisture sensor, SH1Tx and their values are conveyed to the microprocessor in a serial digital data format, SO_T/ SO_{RH} (12Bit or 14Bit), as shown in Fig. 3. The sensor provides also signal processing on a tiny foot print and provides a fully calibrated digital output. A unique capacitive sensor element is used for measuring relative humidity while temperature is measured by a band-gap sensor. The applied CMOSensR technology guarantees excellent reliability and long term stability. The sensor is seamlessly coupled to a 14bit analog to digital converter and a serial interface circuit. This results in superior signal quality.

$$T = d_1 + d_2 \cdot SO_T$$

VDD	d1 (°C)	d1 (°F)
5V	-40.1	-40.2
4V	-39.8	-39.6
3.5V	-39.7	-39.5
3V	-39.6	-39.3
2.5V	-39.4	-38.9

SO_T	d2 (°C)	d2 (°F)
14bit	0.01	0.018
12bit	0.04	0.072

$$RH_{true} = (T_{°C} - 25) \cdot (t_1 + t_2 \cdot SO_{RH}) + RH_{linear}$$

SO_{RH}	t_1	t_2
12 bit	0.01	0.00008
8 bit	0.01	0.00128

$$T_d(RH, T) = T_n \cdot \frac{\ln\left(\frac{RH}{100\%}\right) + \frac{m \cdot T}{T_n + T}}{m - \ln\left(\frac{RH}{100\%}\right) - \frac{m \cdot T}{T_n + T}}$$

Figure 3. T, RH and T_d(RH,T) evaluation formula with the sensor SHTx (from [2])

3.3 The HUB

The HUB, depicted in Fig. 3, collects data from the sensor nodes and send appropriate control signals, both wirelessly and through direct connection to a variety of actuators.

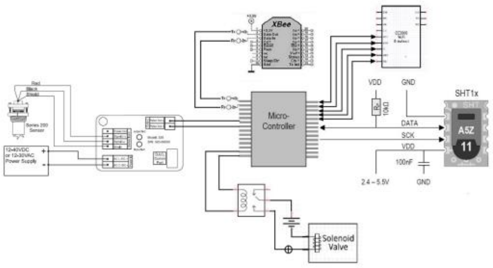


Figure 3. The HUB diagram

The HUB consists of the folllowing components:

- Arduino UNO microprocessor
- Xbee Series 1 Shield
- Solenoid Valve (PESBR)
  Pressure: 20 to 200 psi
  Flow: 0.25 to 200 gpm
- Relay for valve control
- SHT1 temperature sensor
- Flow meter (series 200)/monitor
- WiFi Shield (CC3000)

The main function of the HUB is to:

- Gather data from sensors through Xbee;
- Process data with the microprocessor with Data Smoothing and PID controller scheme;
- Record ambient temperature at the farm;
- Open/close the Solenoid Valve based on threshold (Set Point) set for each crop;
- Sense the water flow and record data;
- Send all data to the “cloud” for internet Access; and
- Provide Watch Dog capability

4 THE FINAL INSTALLATION

4.1 Installation of the solar tracker

The installation of the solar tracker and its accessories was performed by UDC students and staff. UDC has in previous years installed a similar pole-mounted solar tracker system on its main campus []. The same procedure was used during the installation of the system at the farm.

The system comprises the following components:

- A double axis Solar tracker system: AZ-225;
- Nine 6T Helios Solar Panels: 183W x 9
  at typical cell temperature: insolation 800W/m2, ambient temperature 20ºC, wind speed 1m/s;
- Eight “GEL” batteries:12V, 300AH @ 20HR rate;
- One inverter: 2400 WATT, 24VDC, 120VAC;
- One charge controller: C40; and
- One controller box (C200) for level switch and pump ON/OFF control.

4.2 Submersible pump and cistern

A Grundfos submersible pump was installed in a borehole drilled to access an aquifer at about 90ft depth. The 900W, 30-300V DC/AC, 50Hz/60Hz pump has a flow rate of about 10USGPM.

A 5000Gal cistern was also installed in proximity of the borehole in order to minimize usage of pipe. A level switch is inserted in the cistern and sends a pump “shut-off” signal to the C200 controller box, when the water level reaches the preset maximum level.

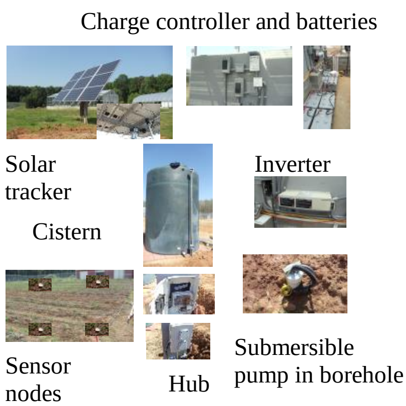
4.3 Sensor nodes, hub and Wi-Fi access

Four sensor nodes were installed in each of the two lots selected in the farm for different crop types.

A Hub is mounted in proximity of the cistern. The components included in the nodes and those in the hub were described in section 3 of this manuscript. Wi-Fi access was also included through a wi-fi shield (C3000).

4.4 Final assembly

The final assembly of the system was completed in early summer 2014. The picture 2 shows the system as it appears at the farm.



Picture 2: Smart irrigation system at Muirkirk Farm

5 Wi-FI access

Wi-Fi access was provided through a wi-fi shield C3000. A cloud website was created and made available to public access through a password. Results of the data processed by the hub could be read. Furthermore, the data obtained through the “cloud” were made available for viewing on a mobile phone. In fact, a Mobile App was implemented and a pdf file of the data can be accessed through a mobile phone as shown in Fig. 4.

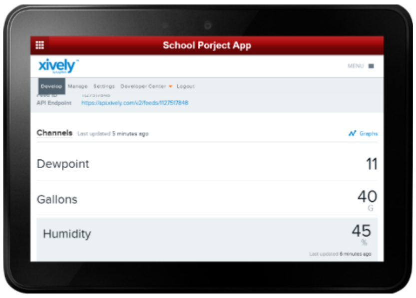


Figure 4. Mobile App for data readout

6 FUTURE PLANS

It is planned to include the following elements to the current installation:

- A remotely accessible video camera for 24/7 viewing of the farm site;
- An remotely accessible anemometer for wind speed monitoring; and
- A remotely accessible water level monitor in the cistern.

7 CONCLUSION AND ACKLOWLEDGMENTS

This project does not only create major solutions for worldwide problems, but also gives alternatives to businesses and farms to grow and become more productive. At the farm owned by The University of the District of Columbia, this system has given an innovative solution to the problems of water conservation and crop productivity. Therefore, the system will help the farm to expand itself, so more crops can be grown in different fields. The project can be considered as a model water delivery system which could be duplicated in various parts of the world where water scarcity is acute.

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