Remote Monitoring and Control of Solar Pumping System Using GSM and Arduino in Egypt

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Abstract – In remote areas, the need of monitoring Solar Pumping Control System (SPCS) is very necessary to ensure stable operation, especially in the changeful weather areas. This paper describes the hardware design for the SPCS in remote areas. The monitoring system is equipped with different sensors to measure the DC electrical output parameters of the PV panel, AC parameters of the inverter, the PV panel's surface and ambient temperatures, the water level in the tank, dust accumulation on the PV panel's surface and wind speed to stow the panel in the case of storms. The system includes a moister sensor to sense the soil wetness and irrigation valves to control the flow of water to tank or to the soil. A GSM modem was used for data transmission and an Arduino microcontroller board was equipped to control the system and to collect the data from the sensors. Finally, a prototype platform for the SPCS was designed and implemented and the experimental results are presented.

Index Terms – Solar pumping control system, GSM and Arduino microcontroller, Remote monitoring and control, Proteus simulator, Prototype platform.

1. INTRODUCTION

Due to the expected crises of oil and water shortages, in particular the shortage of Nile water in Egypt, more reliable new sources of electrical energy and water should be found to compensate for these shortages.

There is a need for pumping water from wells using untraditional energy such as the renewable solar energy. This solar system will pump water from underground wells; also it will pump water from creeks or rivers, which near the ground level. Using this system will replace the use of petrol powered pumping which is a costly operation for farmers in both nearby areas from the electric networks as well as remote areas.

The amount of land that can be cultivated with available underground water with depth from 5m to 133m is 2,592,950 feddans. Afeddan is a unit of area in Egypt. It is divided into 24 kirat in which one kirat equals 175m2. While the amount of land that can be cultivated with available underground water less than a depth of 10 m is 485000 feddans, nearly 20% of the total [1].

Dust accumulation on the PV panels surface is one of the more significant problems that cause the decrease of the system efficiency. At the Solar energy Department, National Research Centre, in Egypt, the efficiency of the tested PV pumping system is decreased at the end of 7 weeks by 36% from its original efficiency at clear condition `[2]. The frequency of cleaning the PV panels depends on the environment of the solar installation. Then it should be using a PV panels cleaning system to maintain the solar system efficiency as at surface clear condition. The proposed SPCS monitoring and control system contains a dust sensor which is used to monitor dust levels and activate the cleaning system.

Traditional monitoring method for the solar systems requires close maintenance from staff for continuously monitoring to follow results that are taken directly from the sensors. Mostly, solar power systems are placed in remote areas. The environment factor can degrade PV power performance [3].

Various methods are used to monitor these systems. Wireless transmission is one of the alternatives to monitor PV systems. Wireless medium has the flexibility function which does not require staff to be in actual area where the solar panels are located to control and monitor the system. Previous work shows that PV modules can be monitored using wireless sensor networks [4]. There are many drawbacks when using wireless sensor network to transmit data. Wireless sensor network consume more energy to operate. These drawbacks made it less reliable for data transmission. Many other transmission techniques can be used for monitoring the remote operated systems as Ethernet network, RF module and Zigbee wireless network. Ethernet uses network cable to transmit data. Hence, it is affected by geographical environment [5]. While transmission bit error rate of RF module is high and less reliable [6]. Zigbee wireless network is more costly compared to other module. Furthermore, Zigbee is complex and it has limited signal range [7].

GSM (Global System for Mobile Communication) is a standard set used to describe protocols for digital cellular networks. GSM technology contains essential intelligent functions to support personal mobility. GSM network has low error rate, low costs and wide signal coverage. Users can communicate easily using GSM to perform monitoring anytime and

anywhere. Hence, provides higher reliability in data transmission. In this work, a stable and reliable system is built using Arduino microcontroller and GSM module to monitor and control performance of the SPCS system. GSM module is wireless modem that transmits data using radio waves. Architecture of the GSM is similar to the mobile architecture [8].

GSM modems are generally used in many electronic applications and they are required to interface with the microcontrollers.

The aims of proposed system are:

i. Collecting and monitoring the data from SPCS sensors as temperature, humidity, solar radiation, wind speed, dust accumulation, soil moister, and water level in the tank.

ii. Take the appropriate decision based on the analysis of collected data by an authorized person or , in some cases, by the system itself as follows:

- Tuning the pumping system on based on the working measurements of soil wetness, wind speed, and an activation remote signal sent by the user,
- Turning the system off in the case of the water tank is full, rains clouds and storm and stowing it.
- Washing the PV array surfaces before a critical accumulation of the dust on the surfaces.

2. PROPOSED SPCS REMOTE MONITORING HARDWARE

As shown in Fig. 1, the system contains Arduino Leonardo microcontroller board, moisture sensor, character Liquid Crystal Display (LCD) that uses the HD44780 driver. Real Time Clock (RTC), temperature sensors. Also, the system contains LEDs and GSM module (SIM808). The control system also contains relays, solenoid valves, main water pump for irrigation and small water pump for the PV panels surface cleaning. Also flow sensor is connected to the main water supply which tracks the water supplied to the field continuously. The used sensors in the system should be waterproof. In addition, the control system contains dust sensor and dc stowing motor. The system will be able to work at full automated state. The water level sensor senses the level of the water in the water tank. Also the system contains K type thermocouple for ambient and PV panels surface temperature sensing. The system will fully derive its energy from the PV system and thus saving energy consumption from traditional electric energy sources and is environmentally friendly, no pollutions and capable to work in remote isolated areas. A 12V, 100A solar battery is charged from the PV panels and used to energize the control and monitoring system. The battery and other not waterproof components should be contained in waterproof cases.

2.1. The Major Parts of the proposed SPCS system are,

2.1.1. Arduino Microcontroller Board

Arduino is an open-source platform and easy-to-use hardware and software. The selected Arduino Leonardo is a microcontroller board based on the ATmega32u4.

It has 20 digital input/output pins (of which 7 can be used as PWM outputs and 12 as analog inputs), a 16 MHz crystal oscillator, a micro USB connection, a power jack, an ICSP header, and a reset button [9]. The SPCS monitoring system requires 17 digital I/O, and 10 analog I/O for data acquisition and control.

2.1.2. GSM Module – SIM808

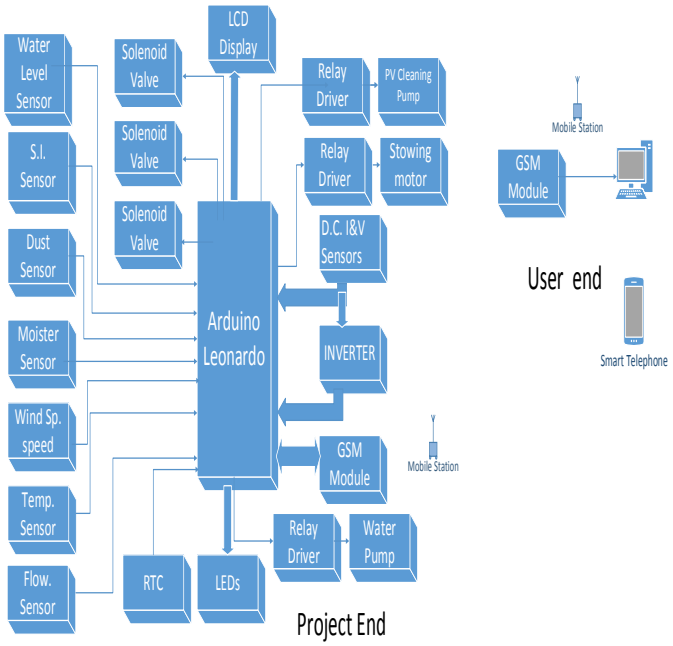

Fig. 1 Proposed SPCS monitoring and control system.

GSM is a standard developed by the European Telecommunications Standards Institute. SIM808 is a GSM/GPRS-compatible Quad-band cell phone, which works on a frequency of 850/900/1800/1900MHz and which can be used not only to access the Internet, but also for oral communication (provided that it is connected to a microphone and a small loud speaker), and for SMSs. Attention (AT) commands are used to control functionality of GSM modem. Two modes can be implemented to give commands to GSM modem like Protocol Description Unit (PDU) and text mode. These modes are based on AT command sets. In this work a text mode is used.

The basic AT Commands for initializing and testing GSM module are [10],

AT, AT+CMGF=1, AT+CMGS="MOBILE NO.", AT+CMGL, AT+CMGD.

3. FLOW CHART OF THE SPCS

The data is collected by Arduino from the sensors connected to it and thus the appropriate decision is taken to control the system performance by using the back SMS from the user.

The user communicates with the microcontroller through SMS using the GSM network. A SIM card is installed in the GSM module which is on the field and connected to the microcontroller. The GSM module sends the data received to Arduino which also continuously receives the data from the sensors. When the user sends an activation code for initiating the GSM and system, the control system checks the wind speed. In the case of storm, the controller sends a signal to stowing motor to stow the PV Panels. Else it checks the status of the accumulated dust upon the PV panels and cleans them in case of critical amount of dust.

The system checks the water level of the tank and time. In the case of full tank it sends SMS to the user to determine "Which Solenoid is to be energized". Else the system turns the pump on and reverts back again to the user. The pump is controlled by a relay circuit. A constant monitoring of soil Moisture is done and once the present soil moisture set point is reached the system is automatically sends an urgent SMS to the user to turn the system off or to take any actions. After few minutes, determined by the expert, in the case of user not back the control SMS with an expected action, the controller automatically turned the pump and valves off and the Microcontroller of the SPCS system enter to Power-down sleeping mode. Also the GSM module well enters to sleeping mode to achieve low power consumption. The user can send SMS to wake up the GSM module and then by a pin change interrupt from the GSM to the microcontroller to wake up the SPCS system. The flow chart of the system is shown in Fig.2.

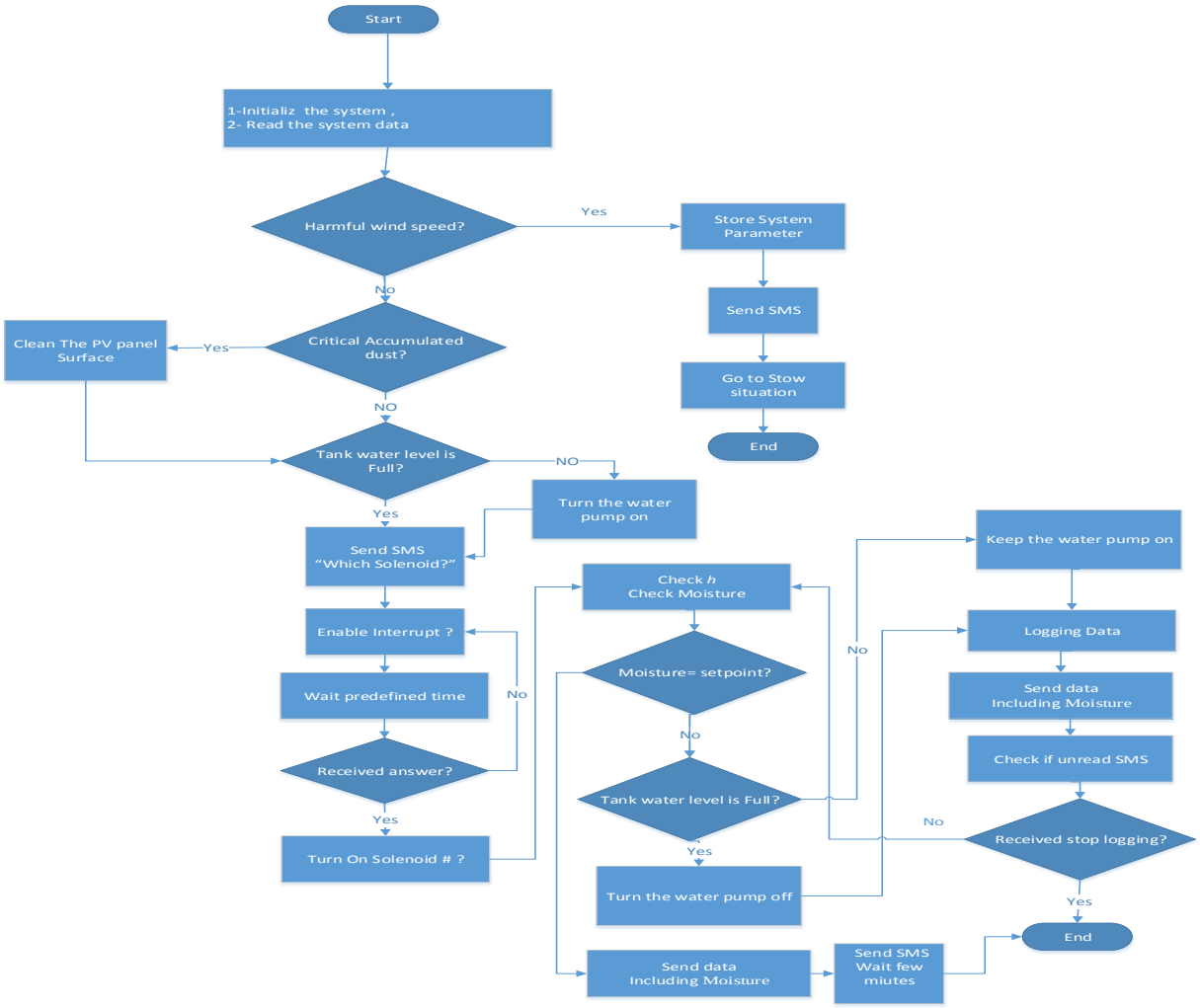

Fig. 2 SPCS system flow chart

4. SIMULATION WORK DESCRIPTION

Simulation was done by using the following:

Arduino software (IDE): for programming the microcontrollers, the Arduino Company provides software application or IDE based on the processing project, which includes C, C++ and Java programming software. It also support for embedded C, C++ and Java programming software. Embedded C is a set of language extensions for the C Programming language by the C Standards committee to address commonality issues that exist between C extensions for different embedded systems.

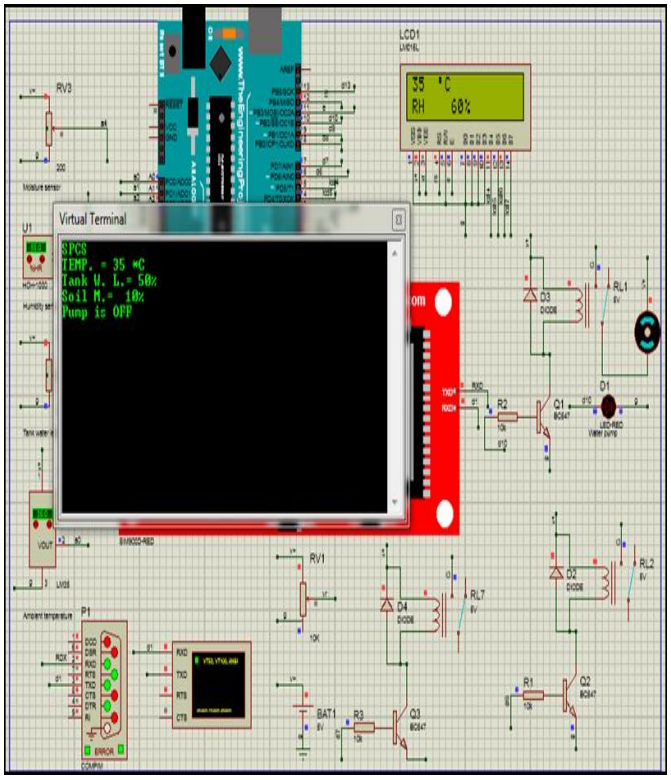

Fig. 3 Circuit diagram on Proteus software when the pump is at OFF state.

- Proteus Isis7 Simulator: Proteus is software developed by Lab Center Electronics for electronic circuit simulation, schematic capture and PCB design. Proteus is commonly useful for digital simulations such as microcontrollers and microprocessors. It can simulate LCD, LED, relays and USB communications etc.

The program that used in controlling the system is written using C ++ programming language. After the program has been written, it was compiled using Arduino IDE in order to generate the microcontroller compatible HEX files. Fig. 3 shows the circuit before turning the pump ON. The LCD shows temperature is 35 ºC and relative humidity is 60% while the pumping system and other relays are not working.

The virtual terminal that appears on Proteus windows, as in Figs. 3, 4 , are for the microcontroller in the circuit. The figures show how the current status of the system that will be sent by the Arduino to the remote user mobile to inform him the pumping system data to take the required action. The remote mobile should read SMS and revert back the action that should be carried out by the microcontroller in the circuit.

The virtual terminal shows in Fig. 4 the contents of the SMS that will be sent to the remote user using the SIM808 GSM board. The contents of SMS as shown on the virtual terminal is,

"SPCS,

Temp. = 35ºC,

Tank W. L. =50%,

Soil M. =10%,

Pump is OFF".

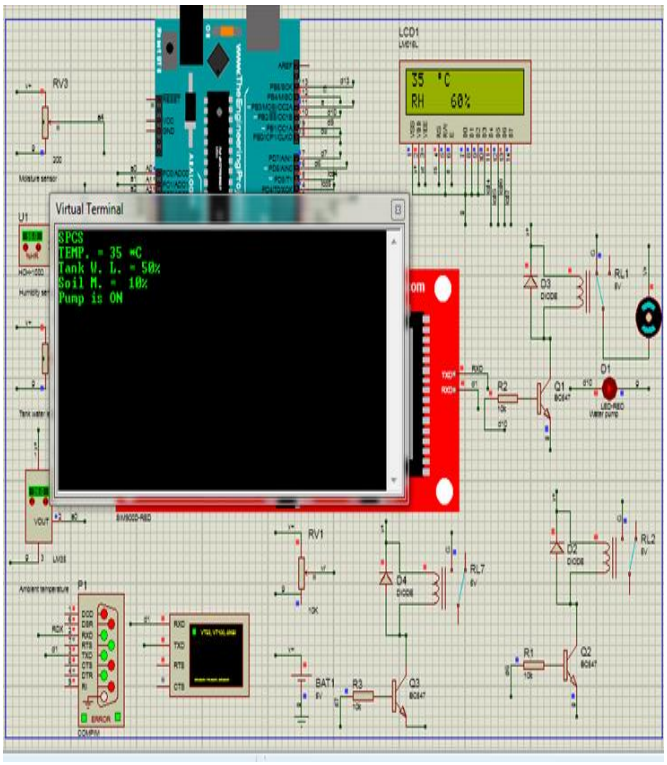

Fig. 4 Diagram shows action of the SPCS after sending the activation code.

The first line is the name of the project, while second, third lines and the rest of the message simultaneously are the ambient temperature, the water level in the tank, the soil moisture percentage, and the pump at OFF state. While in Fig.

4 , the virtual terminal, after receiving a back SMS from the user containing the activation code, it will send a confirmation SMS to the user as follow,

"SPCS, Temp. = 35ºC, Tank W. L. =50%, Soil M. =10%, Pump is ON".

The above SMS will be sent back to the user to inform him that the pump is turned ON due to activation code. The above simulation is a brief simulation for the SPCS system.

5. SPCS PROTOTYPE DESIGN

SPCS prototype consists of smart mobile, arduino UNO, SIM808 GPRS / GSM module ,4 relays module, DH11 temperature and humidity sensors module, 4X4 keypad , 16 X 2 LCD character display, bread board, resistors, LEDs and wires as shown in Figs. 5,6. The sensors used here in this laboratory test are not waterproof (i.e for lab. test). The Arduino UNO is the most widely used board for developing Arduino projects.

An Atmel ATmega328 chip is the heart of Arduino UNO. Arduino UNO has 14 digital input/output pins (of which 6 can be used as PWM outputs and 6 as analog inputs), a 16 MHz crystal oscillator, a micro USB connection, a power jack, and a reset button [11].

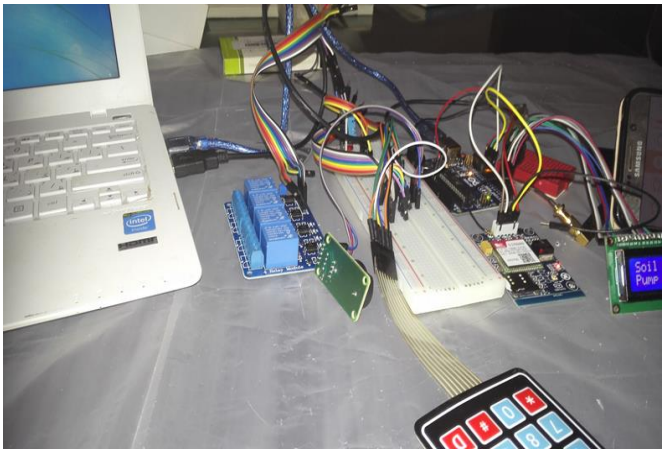

Fig. 5 Photo shows the SPCS system, project end.

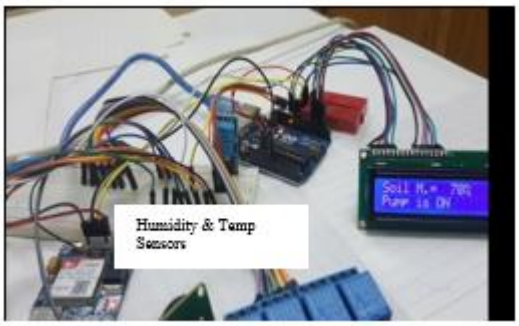

Fig. 6 Humidity and temperature sensors

The Moisture sensor in the prototype system was replaced by variable resistor to detect the amount of water in the soil. The resistance of the soil is decreased, as the water quantity is increased and vice versa.

The controlled devices as valves were replaced by LEDS. SIM card was inserted in SIM808 module, as shown in Fig. 7 , to receive and send text messages, from/to the user mobile phone.

Fig. 7 GSM module include SIM card.

Relay module was connected to the Arduino board and allows turning on and off the pump or any other devices, both AC and DC, based on the received SMS from the authorized user.

The orders received by the relay module that has been sent by Arduino are used to turn on or off the system controlling switch. Figure 8 shows photo for the prototype including the project and the user end. The smart mobile acts as user end.

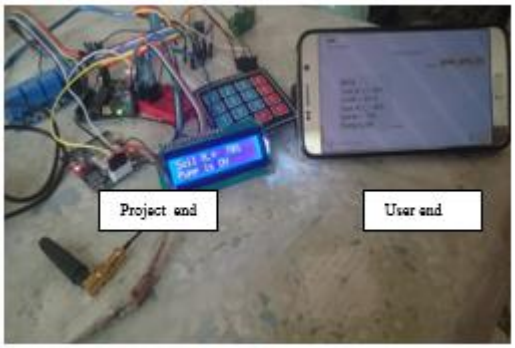

Fig. 8 SPCS system and user end.

6. RESULTS AND DISCUSSIONS

The Arduino will process the data and control relays in accordance with the received data.

If the relay is ON, the electrical equipment such as water valves, and others will be ON as well and if the relay off the electrical equipment will be off as well. Testing was done by SMSs exchange between the project and user ends.

When we send some commands in the form of strings to the project end as "$SND_SPCS_ST/" to receive the system status

as RH, temperatures, soil moisture content and so on. After receiving this SMS by SPCS, it compares the received string with predefined strings and collects the required data and then sends it to the user. As shown in Fig. 9," Sector1 Soil M. =10%", means soil moister of the sector 1 at the farm is under irrigation and needs to irrigate, %", assuming that the farm was divided into three sectors.

Fig. 9 Response of the SPCS system to the user SMS $SND_SPCS_ST/.

And the water tank level is under the desired level. The shown LCD in the figures is connected to SPCS system (Project end). The user reply SMS to the system contains "$P_T_ON" and "$SECTOR1_V_ON" to turn both the pump and sector 1 valve ON as shown in Fig.10.

Fig. 10 Response of the SPCS system due to user SMS "$P_T_ON" and "$SECTOR_1_ON"

Fig. 11 Response of the SPCS system to user SMSs "$SECTOR_1_OFF", and, "TANK_ON".

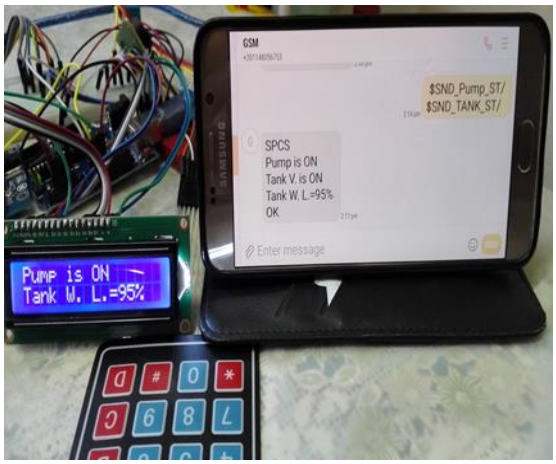

Fig. 12 SPCS system response to $P_T_OFF/ and $SPCS_OFF/ commands

In figure 11, the user received an urgent SMS contains "SPCS, URGENT, Sector1 S. M. is 85%, Tank W. L. =70". The command "Sector1 S. M. is 85%" means that the plants or trees at sector 1 are irrigated based on the type of the plants or trees. And "Tank W.L. =70%", means that the tank water level still under the desired level.

The user reverts back SMS contains the instructions" $SECTOR_1_OFF", and, TANK_ON". This SMS tills the system to turn the valve of sector1 OFF and keeps the pump turning ON to reach to the required water tank level. At end of the day task, the user sends SMS to the SPCS system to turn the pump off and to enter the system the Power-down sleeping mode as depicted in Fig. 12.

Finally, in Fig.13, LEDs which represent different valves that can be opened or closed the path of water flow to any sector of the farm.

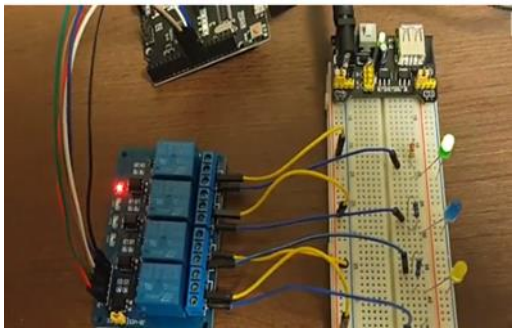

Fig. 13 LEDs represent pump is ON and valve of sector 1 is turned ON and other sector valves are OFF.

In the current case the figure shows when LED1 of the sector 1 valve is ON to irrigate this sector.

From the above tests we can conclude that the prototype system respond correctly to the SMS sent by the authorized user. The SPCS collects the required system data and revert back this to the user that can help him to take the appropriate actions.

7. CONCLUSION

Solar pumping system offers an alternate means to meet the electricity demand for irrigation and livestock watering. Under the circumstances of inadequate supply of conventional sources of energy, the solar water pump can play a significant role.

By knowing the status of soil moisture and rest data collected by the SPCS monitoring system, water flow can be controlled by just sending a message from the user mobile any time anywhere. Also the system will avoid over and under irrigation, and reduce the wastage of water. The proposed system will save time and money and increases the system efficiency due to the early faults detection that can be analyzed by the user or the system supervisor. Also, this study has shown that using independent stand-alone devices based on microcontrollers will reduce the implementation cost and increase the system stability. Finally due to the environmental problems as a result of overpopulations, the renewable and free pollution energy systems are recommended.

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