AUTOMATEDIRRIGATION SYSTEM

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***Abstract* — Population growth and increased food demand results in urgent need take measures to sustain use of water technically as well as agronomically. An automated irrigation system was developed to optimize water usage for agricultural crops. The system has a distributed wireless network of soil moisture and temperature sensors placed in the root zone of the plants. In addition, a gateway unit handles sensor information from sensors and glows an LED in display board. An algorithm was developed with threshold values of temperature and soil moisture that was programmed into microcontroller-based gateway to control water quantity. The system was powered by photo voltaic panels. The irrigation system can be adjusted to a variety of specificcrop needs and requires minimum maintenance. By using this way we can save water up to 90% compared with traditional irrigation practices. Because of its energy autonomy and low cost, the system has the potential to be useful in water limited and geographically isolated areas.**

1 INTRODUCTION

India is an agriculture based economy. Most of the people depends on agriculture for their livings. Water is an important determinant factor of production of crops in agriculture sector. Intensive and extensivecultivation of land depend mainly on the availability of water .But the per capita income of most of the Indian farmers is low due to which lots of the farmers commit suicide. It is necessary to avoid the unnecessary or excess application of water, fertilizers etc. in the field so as to make farming more profitable which in turn will help India grow more rapidly and that too from grass root level.

This paper aims to achieve water savings in various Crops. An algorithm was developed with threshold values of temperature and soil moisture that was programmed into a microcontroller-based gateway to control water quantity. The system was powered by photovoltaic panels.Let us see briefly about this paper.

II. SYSTEM DESCRIPTION

In Tamilnadu farmers use various types of irrigation system based on the water resources.Only the 11 districts in tamilnadu has good rain density. Rest of that areas we use river water for cultivation.In Coimbatore,erode and tanjore they use river water for cultivation. In areas near by hills they use well water for irrigation. It is not enough for that places. so we have to find the solution for this problem.

In this paper, the development of the deployment of an automated irrigation system based on microcontrollers andWireless communication at experimental scale within ruralareas is presented. The aim of the implementation was to demonstrate that the automatic irrigation can be used to reducewater use. The implementation is a photovoltaic poweredautomated irrigation system that consists of a distributed wireless network of soil moisture andtemperature sensors deployed in plant root zones. Each sensor node involved a soil-moisture probe, a temperature probe, a microcontroller for data acquisition, and a radio transceiver; the sensor measurements are transmitted toa microcontroller-based receiver.

This gateway permits the automated activation of irrigationwhen the threshold values of soil moisture and temperatureare reached. Communicationbetween the sensor nodes andthe data receiver is via the Zigbee protocol. Then we get the outputvia glowing of LED's. Becausethe soil-moisture and temperature levels are shown visually. Because ofits energy autonomy and low cost, thesystem has potential use for organic crops,which are mainlylocated ingeographically isolated areas.

III. AUTO MATED IRRIGATION SYSTEM

The automated irrigation system hereby reported, consisted of two components , wireless sensor units (WSUs) and a wirelessinformation unit (WIU), linked by radio transceivers that allowed the transfer of soil moisture and temperature data, implementing a WSN that uses ZigBee technology. Then the data has been displayed by using different colour LED's.

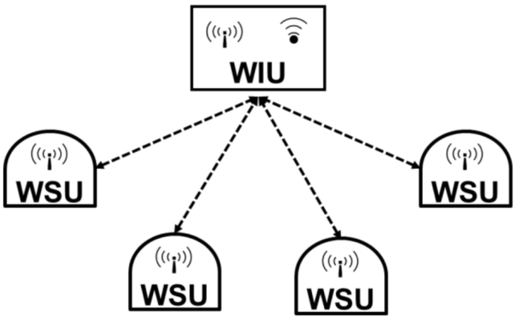

Fig. 1.Configuration of the automated irrigation system. WSUs and a WIU, based on microcontroller, ZigBee, and GPRS technologies.

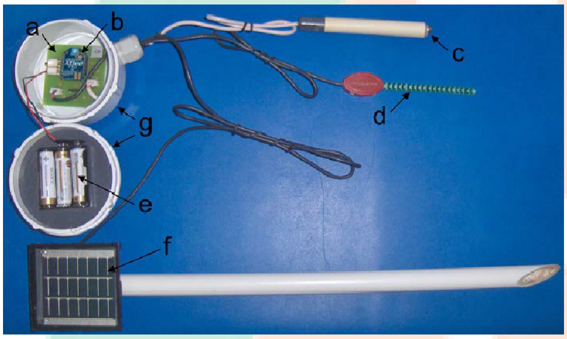

Fig. 2. WSU. (a) Electronic component PCB. (b) Radio modem ZigBee.(c) Temperature sensor. (d) Moisture sensor. (e) Rechargeable batteries.(f) Photovoltaic cell. (g) Polyvinyl chloride container. Fig. 2. WSU. (a) Electronic component PCB. (b) Radio modem ZigBee.(c) Temperature sensor. (d) Moisture sensor. (e) Rechargeable batteries.(f) Photovoltaic cell. (g) Polyvinyl chloride container.

A. *Wireless Sensor Unit*

A WSU is comprised of a RF transceiver, sensors, amicrocontroller, and power sources. Several WSUs can bedeployed in-field to configure a distributed sensor networkfor the automated irrigation system. Each unit is based onthe microcontrollerPIC24FJ64GB004, ZIGBEE and processesinformation from the soil-moisture sensor VH400 , and the temperature sensor DS1822 . These components are powered by rechargeable AA 2000-mAh Ni-MH CycleEnergy batteries. The charge is maintained by a photovoltaic panel MPT4.8-75 (PowerFilm Solar, Ames, IN) to achieve full energy autonomy. The microcontroller, radio modem, rechargeable batteries, and electronic components were encapsulated in a waterproof Polyvinyl chloride (PVC) container.These components were selected to minimize thepower consumption for the proposed application.

1.Single-Chip PIC24FJ64GB004

A 16-bit microcontrollerwith 44-pins and nanoWatt XLP technology that operatesin a range 2.0 to 3.6 V at 8 MHz with internal oscillator.It has up to 25 digital input/output ports, 13-, 10-bit analogto-digital converters (ADC), two serial peripheral interfacemodules, two I2C, two UART, 5 16-bit timers, 64 KB of program memory, 8 KB of SRAM, and hardware real-timeclock/calendar (RTCC). The microcontroller

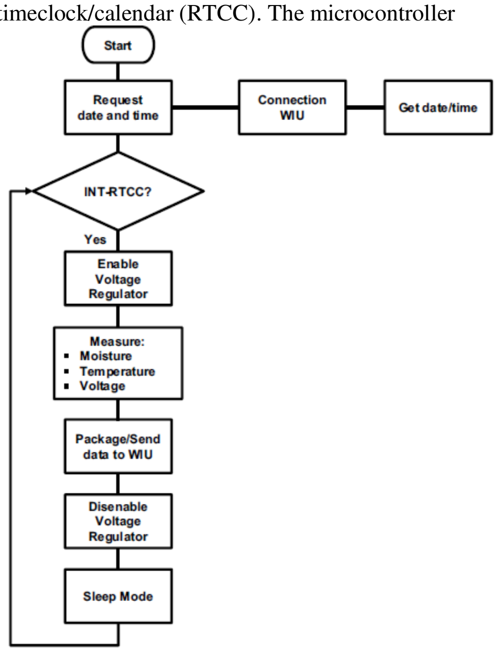

Fig.3.algorithm for microcontroller

is well suited forthis remote application, because of its low-power operatingcurrent, which is 175 μA at 2.5 V at 8 MHz and 0.5 μA forstandby current in sleep mode including the RTCC.The microcontroller was programmed in C compiler with the appropriatealgorithm for monitoring the soil-moisture probethrough an analog-to-digital port and the soil-temperatureprobe through another digital port, implemented in 1-Wirecommunication protocol. A battery voltage monitor is includedthrough a high-impedance voltage divider coupled to analog -to-digital port. The data are packed with the correspondingidentifier, date, and time to be transmitted viaXBee radio modem using a RS-232 protocol through twodigital ports configured as transmitter (TX) and receiver (RX),respectively. After sending data, the microcontroller is set insleep mode for certain period according to the sensor samplingrate desired, whereas the internal RTCC is running. Thisoperation mode allows energy savings. When the WSU islaunched for first time, the algorithm also inquires the WIU, Communication frames between a WSU and the WIU.the date and time to program the RTCC, and periodicallyit for synchronization.

2.ZigBee Modules:

ZigBee technologies based on short rangeWSNandit was selected for thisbattery-operated sensor network because of its low cost, lowpower consumption, and greater useful range in comparisonwith other wireless technologies like Bluetooth, UW, and Wi-Fi . The ZigBee devices operate in industrial, scientific,and medical 2.4-GHz radio band and allow the operationin a so-called mesh networking architecture, which can bedifferentiated into three categories: 1) coordinator; 2) router;and 3) end device.

From a wide range of commercial ZigBee devices, theXBee-PRO S2 is an appropriate original equipment manufacturermodule to establish communication between a WSU andthe WIU because of its long-range operation and reliability ofthe sensor networking architecture. The XBee-PRO S2 is a RFmodem with integrated chip antenna, 20-pins, and 13 generalpurpose input/output (GPIO) ports available of which four areADC. It can operate up to a distance of 1500 m in outdoorline-of-sight with 170 mA of TX peak current and 45 mA forRX current at 3.3 V and power-down current of 3.5 μA.The XBee radio modem of each WSU is powered at 3.3 Vthrough a voltage regulator ADP122AUJZ-3.3-R7 and interfaced to the host microcontrollerthrough its serial port, a logic-level asynchronous serial, and voltage compatible UART configured at 9600 baud rate,no - parity, 1 - start bit, 1 - stop bit, 8 - data bits.The WSUs were configured such as end devices to deploya networking topology point-to-point based on a coordinatorthat was implemented by the XBee radio modem of the WIU.An end device has the following characteristics:

1. it must joina ZigBee PAN before it can transmit or receive data;
2. cannotallow devices to join the network;
3. must always transmit andreceive RF data through its parent;
4. cannot route data; and
5. can enter low power modes to conserve power and can bebattery powered.

The least significant byte of the unique 64-bitaddress is used to label the information of the soil moistureand temperature for each WSU in the network. This byte isregistered in the WIU as the identifier (ID) associated to eachWSU. As shown in the sample frames to request date/time,receive date/time, and send data packaged to the WIU.

3) Soil Sensor Array:

The sensor array consists of two soilsensors, including moisture and temperature that are inserted inthe root zone of the plants. The VH400 probe was selected to estimate the soil moisture because of low power consumption(<7 mA) and low cost. The probe measures the dielectricconstant of the soil using transmission line techniques at80 MHz, which is insensitive to water salinity, and providesan output range between 0 and 3.0 V, which is proportional tothe volumetric water content (VWC) according to a calibrationcurve provided by the manufacturer. The sensor was poweredat 3.3 V and monitored by the microcontroller through an ADCport.Soil temperature measurements were made through the digitalthermometer DS1822. The sensor converts temperature toa 12-bit digital word and is stored in 2-B temperature registers,corresponding to increments of 0.0625 °C. The temperature isrequired through a reading command and transmitted using 1-Wire bus protocol implemented in the microcontrollerthrough one digital port. The thermometer has ±2.0 °Caccuracy over −10 °C to +85 °C temperature range and aunique 64-bit serial number. The sensor is a 3-pin single-chipand TO92 package that was embedded in a metal capsule andsealed in a waterproof PVC cylindrical container.

To calibrate the soil moisture, several samples were preparedwith 1 kg of dry soil from the crop area. Its composition wasloamy sand with 80% sand separate, 4.5% clay separate, and 915.6% silt separate. The soil water holding capacity was of20.7% VWC corresponding to measured output voltages of1.45 V. The temperature sensors were calibrated through areference mercury thermometer CT40, with 0.1 °C divisionsand a range from −1 °C to 51 °C. The thermometer and thetemperature sensors were placed in an insulated flask filledwith mineral oil at 10 °C and 40 °C.

4) Photovoltaic Cell:

To maintain the charge of the WSUbatteries, a solar panel MPT4.8-75 was employed. Each solarpanel delivers 50 mA at 4.8 V, which is sufficient energyto maintain the voltage of the three rechargeable batteries.A MSS1P2U Schottky diode (Vishay, Shelton, CT) is usedto prevent the solar module and to drain the battery whenis in the dark. The solar panel is encapsulated in a 3-mmclear polyester film with dimensions of 94 mm × 75 mm.This flexible panel was mounted on a PVC prismatic base(100 mm × 80 mm × 3.17 mm) that is fastened in the upperpart of a PVC pole allowing for the correct alignment of thephotovoltaic panel to the sun. The stick is 50 cm of lengthand 12.5 mm of diameter; the lower end of the pole had a tipend to be buried.

B. Wireless Information Unit

The soil moisture and temperature data from each WSU arereceived, identified, recorded, and analyzed in the WIU. TheWIU consists of a master microcontroller PIC24FJ64GB004,an XBee radio modem, a GPRS module MTSMC-G2-SP, an RS-232 interfaceMAX3235E , twoelectronic relays, two 12 V dc 1100 GPH Livewell pumps for driving the water of thetanks, and a deep cycle 12 V at 100-Ah rechargeable batteryL-24M/DC-140, which is recharged by a solarpanel KC130TM of 12 V at 130 W . All the WIU electronic components were encapsulated in a waterproof PVC box . The WIU canbe located up to 1500-m line-of-sight from the WSUs placedin the field.

1) Master Microcontroller:

The functionality of the WIU isbased on the microcontroller, which is programmed to performdiverse tasks. The first task of theprogram is to download from a web server the date and timethrough the GPRS module. The WIU is ready to transmitvia XBee the date and time for each WSU once powered.Then, the microcontroller receives the information packagetransmitted by each WSU that conform the WSN.

These data are processed by the algorithm that first identifiesthe least significant byte of a unique 64-bit address encapsulatedin the package received. Second, the soil moistureand temperature data are compared with programmed valuesof minimum soil moisture and maximum soil temperatureto activate the irrigation pumps for a desired period. Third,the algorithm also records a log file with the data in a solidstate memory 24FC1025 ,with a capacity of 128 kB. Each log is 12-B long,including soil moisture and temperature, the battery voltage,the WSU ID, the date, and time generated by the internalRTCC. If irrigation is provided, the program also stores aregister with the duration of irrigation, the date, and time.Finally, these data and a greenhouse ID are also at each predefined time to a web server through HTTP via theGPRS module to be deployed on the Internet web applicationin real time.

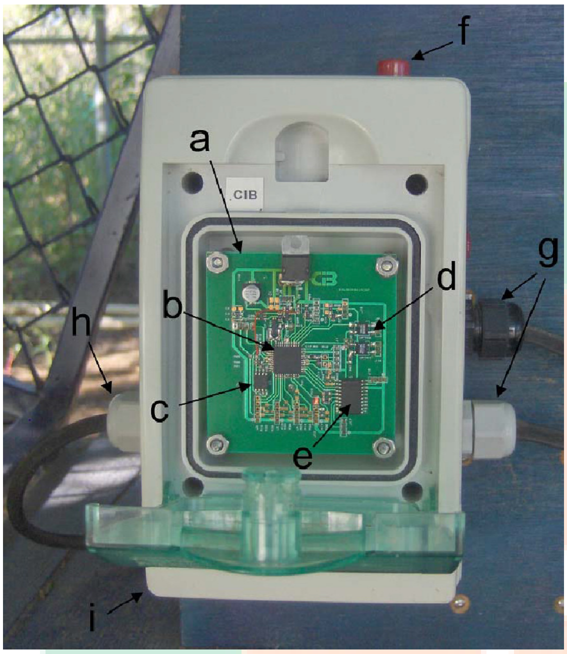

Fig. 5. WIU. (a) Electronic component PCB. (b) Master microcontroller.(c) Solid state memory. (d) Optical isolators. (e) RS-232 interface. (f) Pushbutton. (g) Output cables to pumps. (h) Supply cable from charge controller.(i) PCV box.through a PWM charge controllerSCI-120 (Syscom, Mexico).

When the server receives a request for the web page, itinserts each data to the corresponding field in the database.This link is bidirectional and permits to change the thresholdvalues through the website interface; scheduled watering orremote watering can be performed.The WIU has also a push button to perform manual irrigationfor a programmed period and a LED to indicate when theinformation package is received. All the WIU processes canbe monitored through the RS-232 port.The WIU includes a function that synchronizes the WSUsat noon for monitoring the status of each WSU. In the casethat all WSUs are lost, the system goes automatically to a irrigation schedule mode. Then the led's will glow.

2) Watering Module:

The irrigation is performed by controllingthe two pumps through 40-A electromagnetic relaysconnected with the microcontroller via two optical isolatorsCPC1004N . The pumps have a powerconsumption of 48 W each andwere fed by a 5000-l watertank.Four different irrigation actions (IA) are implemented in theWIU algorithm:

1) fixed duration for manual irrigation with the push button;

2) scheduled date and time irrigations through the web pagefor any desired time;

3) automated irrigation with a fixed duration, if at least onesoil moisture sensor value of the WSN drops below theprogrammed threshold level;

4) automated irrigation with a fixed duration, if at least onesoil temperature sensor value of the WSN exceeds the programmed threshold level.

IV. Irrigation System Operation

The greenhouse had 56 productionbeds covered with plastic. Each bed was 14-m long andhad two black polyethylene tubes with drip hole spacingof 0.2 m. The automated irrigation system was usedto irrigate only 600 m2, which corresponded to 14 beds;whereas, the remaining 42 beds were irrigated by humansupervision to compare water consumption with the traditionalirrigation practices in this production place. FourWSUs labeled by the last significant byte of the unique64-bit address (WSU-54, 55, 56, and 57) were located in thegreenhouse at arbitrary points.TheWSU-57 unit was used to measure the soil moisture andtemperature in the area (bed 23) where the traditional irrigationpractices were employed. The other three units (WSU-54,55, and 56) were located in beds 1, 2, and 12 to operatethe automated irrigation system with their corresponding soilmoisture and temperature sensors situated at a depth of 10 cm. Gathered data of the WSUs, in the web application of the automatedirrigation system: soil temperatures, soil moisture, and water supplied (verticalbars indicate automated and scheduled irrigation).in the root zone of the plants. These three units alloweddata redundancy to ensure irrigation control. The algorithmconsidered the values from the WSU-54, 55, and 56, if onereached the threshold values the automated irrigation wasperformed.The pumping rate provided 10 ml/min/drip hole, which wasmeasured in the automated irrigation zone in six different dripholes.

In accordance with the organic producer's experience, aminimum value of 5% VWC for the soil was established asthe moisture threshold level and 30 °C as the temperature threshold level for the automated irrigation modes (IA-3 andIA-4, respectively). Initially, the scheduled irrigation (IA-2)of 35 min/week was used during the first six weeks. Afterthat, the scheduled irrigation was set at 35 min three timesper week. Sage cultivation finalized after 136 days.During the cultivation, several automated irrigation periodswere carried out by the system because of the soil-moisture(IA-3) or temperature (IA-4) levels, regardless of the scheduledirrigation (IA-2). All data were uploaded each hour to theweb server for remote supervision. For instance, data offive days are shown (Fig. 10). The first graph shows soiltemperatures. The vertical bars indicate automated irrigationperiods triggered by temperature when soil temperature wasabove the threshold value (30 °C). The second graph showssoil moistures that were above the threshold value (5.0%VWC), and thus the automated irrigation was not triggeredby soil moisture. Finally, the last graph shows the total waterused by the sage with the corresponding scheduled irrigationvertical bars for the IA-2. The dots denote the automated andscheduled irrigation.

Automated irrigation triggered by soil moisture for fourdays are shown in Fig. 11; when the soil moisture value fellbelow the threshold level of 5.0% VWC, the irrigation systemwas activated for 35 min according to IA-3, whereas the soiltemperature remained below the threshold level. Similarly,when the temperature was above 30 °C, the irrigationsystem was activated for 5 min according to IA-4, whereasthe soil moisture remained above the threshold level. Water consumption with the organic producers' traditionalirrigation procedure consisted of watering with a 2" electricalpump during 5 h three times per week for the whole cultivationperiod. Under this scheme thevolume flow rate measured onsite was 10 ml/min/per drip hole, giving a total of 174 l/driphole, whilst the automated irrigation system used 14 l/driphole. In the entire greenhouse, the sage plants presented similarfresh biomass regardless of the irrigation procedure during thewhole production period.

Power consumption of a WSU was measured throughcurrent oscilloscope (UNI-T UT81B) in the monitoring and sleep operational modes Each hour, the soil-moisture and temperature data were transmitted to the WIU. Beforetransmitting the data, the XBee of the WSU was powered onthrough the voltage regulator that was enabled for a periodof 20 s by the microcontroller, which was a long enoughtime for the radio modem to wake up and transmit thedata. Then, the total average power consumption was keptat 0.455 mAh. The charge-discharge cycle of the batteries isshown for 20 days in the winter with the solar panel connectedand disconnected using the data registered by thebattery voltage monitor. Thus, the photovoltaic panel and the batteriesprovide sufficient energy to maintain the WSU running for thewhole crop season at almost any latitude, due the low energyconsumption.

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IV. CONCLUSION

The automated irrigation system implemented was foundtobe feasible and cost effective for optimizing water resourcesfor agricultural production. This irrigation system allowscultivation in places with water scarcity thereby improvingsustainability.The automated irrigation system developed proves that theuse of water can be diminished for a given amount of freshbiomass production. The use of solar power in this irrigationsystem is pertinent and significantly important for organiccrops and other agricultural products that are geographicallyisolated, where the investment in electric power supply wouldbe expensive.The irrigation system can be adjusted to a variety of specificcrop needs and requires minimum maintenance. The modularconfiguration of the automated irrigation system allows it tobe scaled up for larger greenhouses or open fields. Inaddition,other applications such as temperature monitoring in compostproduction can be easily implementedBesides the monetary savings in water use, the importanceof the preservation of this natural resource justify the use ofthis kind of irrigation systems.

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