CHEMICAL ENGINEERING TRANSACTIONS
VOL. 46, 2015
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Peiyu Ren, Yancang Li, Huiping Song

ISBN 978-88-95608-37-2; **ISSN** 2283-9216
DOI: 10.3303/CET1546180

Water-saving Irrigation System Based on Wireless Communication

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According to the characteristics of weak expandability, complex networking, poor communication ability and high running cost of existing system, a new agricultural water-saving irrigation system is design based on data transmission unit (DTU), wireless radio frequency (RF) module and microcontroller, the application of RF module in the acquisition terminal improves the expandability, data of soil moisture are collected by relay station, and then transmitted to the monitoring center by the DTU using GPRS network. Monitoring center devises water-saving irrigation schemes according to the analysis of soil moisture data collected from acquisition terminal, then it send control commands to adjust the irrigation volume of each terminal. The system completes data collection, transmission and analysis, realizes water-saving control. Experimental results show that this system can collect real-time data of soil moisture, maintain the value needed for crop growth. It lays a solid foundation for the further development of precision irrigation system. The whole system powered by solar energy, has the characteristics of simple structure, easy to expand, large volume data transmission, low cost, energy saving and environmental protection, has the value of usage and popularization.

1. Introduction

Soil moisture plays a decisive role on the growth of crops. It is the basic content of precision agriculture to realize the water-saving irrigation on the basis of soil moisture data collected from soil. The resources shortage of fresh water has become a worldwide problem, especially in China. Water shortage limits the economy development. Water saving and higher water use efficiency will be significant factors in agricultural production, H. Navarro-Hellín et al. (2015) reported efficient irrigation water management, Mohammad Hossein Anisi et al. (2014) reported the precision agriculture, Jaume Casadesús et al. (2012) reported precision irrigation in tree crops, and J. García Morillo et al. (2015) reported precision irrigation in strawberry cultivation.

Agricultural irrigation accounts for more than two-thirds of all global freshwater withdrawals, Traditional irrigation rely mainly on water control and mechanical control, technology level, manage level are relatively extensive, a lot of problems exist in the aspect of water-saving, huge energy saving potential is exited. Daudi S. Simbeye et al. (2014); Yunseop K. Evans RG and Iversen WM (2008); Stefanos A. Nikolidakis et al. (2015) reported the ideology of wireless sensor networks for data acquisition, Hu Peijin et al. (2011) and Liai Gao et al. (2013) reported the ideology of using wireless sensor network to collect parameters of soil moisture, communicate with the master PC via interface of RS232. Yue Xuejun et al. (2013) reported automatic irrigation control system based on soil moisture meter. Xiao Kehui et al. (2010) reported that water-saving irrigation control system is realized by using GSM technology, remote data transmission of soil moisture is realized by using GPRS, which was confirmed (Chen Tianhua and Tang Haitao (2012)).

However there are three problems to be solved, First, network is complex in existing system, and adopts the AC power supply, second, second, data will be lost when communication fault occurs in collection terminal, third, transmission distance is short using RS232 communication, the maximum transmission distance is 50 feet, the GSM mode can not be real-time online, and small data volume and high cost of communication.

In view of the above questions, we improved the system referred to in which was confirmed (Liai Gao et al. (2013)), developed a new water-saving irrigation control system, data acquisition terminal using MCU and

Please cite this article as: Zhang D.N., Zhou Z.N., Zhang M., 2015, Water-saving irrigation system based on wireless communication, Chemical Engineering Transactions, 46, 1075-1080 DOI:10.3303/CET1546180

wireless radio frequency (RF) module in networking with star topology. The function of data storage is designed in acquisition terminal, data of soil moisture can be still transmitted to the upper computer correctly in case of transient communication failure, always online can be realized using the GPRS network instead of RS232 and GSM network, the operation cost of the system reduce greatly by using solar power supply.

2. Overall structure and working principle of system

System consists of data transmission unit (DTU) module, wireless data transmission module, the soil moisture sensors, memory, irrigation control module, power module, PC and so on, the single-chip microcomputer to collect data via soil moisture sensor, then send data to the coordinator via wireless RF module, data are uploaded to the monitoring center through GPRS and Internet network by DTU module at last, so as to control consumption of irrigation water by the analysis of the soil moisture data in the monitoring center. Structure diagram of the monitoring system is shown in Figure 1. Antonio-Javier Garcia-Sanchez et al. (2011) reported a new platform called Integrated WSN Solution for Precision Agriculture over distributed crops.

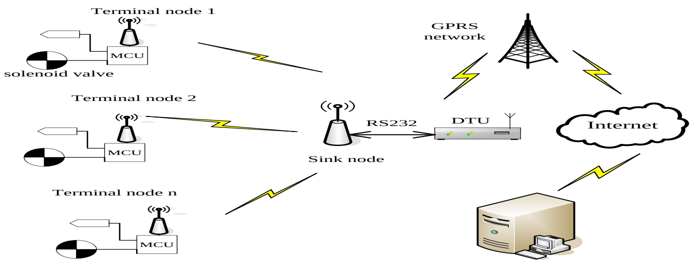

Figure 1: The structure diagram of the overall system

2.1 Terminal node

The terminal is the most front end of wireless communication network, with functions of Information collection and irrigation control. It consists of microprocessor, sensors, memory, wireless RF module, irrigation control module, etc. Sensor module includes soil moisture sensor and the corresponding signal conditioning circuit, irrigation control module includes photoelectric isolation, Solenoid valve drive circuit. The microcontroller collects soil moisture data from sensor module, stores data into the ferroelectric memory, sent to the coordinator via RF module. The structure diagram of terminal node is shown in Figure 2.

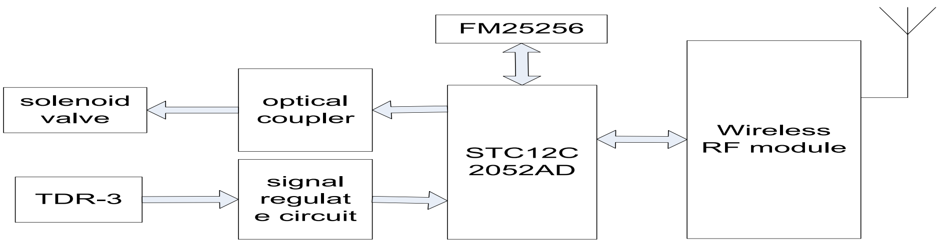

Figure 2: The Structure Diagram of Terminal Node

(a) STC12C2052AD
STC12C2052AD was selected as the microcontroller in this system, a new generation of 8-bit single chip microcomputer with high speed, low power consumption and strong anti-interference. Its instruction code is fully compatible with traditional 8051 CPU, at the same time there are a lot of improvement. It has a wide operating range 3.4 to 5.5V. There are several other characteristics such as 2 KB Flash Program Memory, 2 KB EEPROM, 256 bytes on-chip RAM, 8-channel and 8-bit A/D converter, one duplex USART and one SPI serial bus.
(b) Wireless RF Module
The type of Wireless RF Module is KYL-1020L, produced by ShenZhen KYL Communication Equipment Co, Ltd. It has the features of DC 5V power supply, less than 500 mw output powers, works in industrial scientific medical frequency band, can be set to sleep mode by the Pin8.
(c) Soil moisture sensors
The type of soil moisture sensor is TDR-3, produced by Jinjiang Sunshine Technology Co, Ltd. It is an ideal instrument, has the features of sealed, waterproof, high precision. Soil moisture is measured by Time-Domain

Reflectometry (TDR) probes installed 5 cm above the drip line, which was confirmed (Tomasz Pastuszka et al. (2014) and Andrea Cataldo et al. (2015)). The main performance indexes of the sensor are shown in table 1.

Table 1: Performance indexes of TDR-3

Measured parameters	Performance index
Range	0 ~ 100%
Accuracy	±2%
Measuring field	Cylinder which diameter is 3 cm, length is 6 cm around the probe
Working voltage	12V DC
Working circuit	50mA,
Output	4~20mA
Response time	To steady state within 1 s

(d) External memory module
The ferroelectric memory FM25256 organized as 32,768 x 8 bits is used to store data in this system, which accessed using an industry standard Serial Peripheral Interface (SPI) bus, The access time for memory operation is essentially zero, beyond the time needed for the serial protocol. That is, the memory is read or written at the speed of the SPI bus. Unlike an EEPROM, it is not necessary to poll the device for a ready condition since writes occur at bus speed. So, by the time a new bus transaction can be shifted into the device, a write operation will be complete.

2.2 The coordinator design

As information transfer station of a wireless communication network, coordinator responsible for information exchange between server and acquisition terminal, on the one hand, it receives data collected from the sensor nodes, sends the data to the remote monitoring center via the DTU module, on the other hand it accepts control command issued by monitoring center, then sent command to each terminal, coordinator works on a transparent transmission in this system. It is mainly composed of wireless radio frequency module and DTU module, the structure diagram of coordinator is shown in Figure 3.

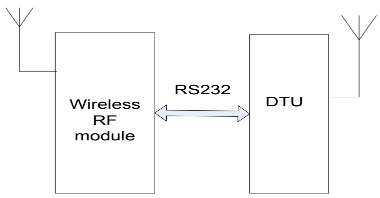

Figure 3: The Structure Diagram of coordinator Module

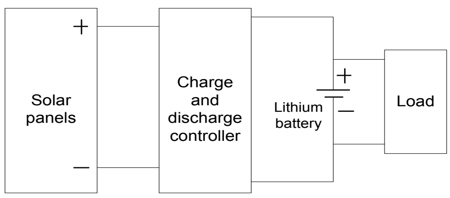

Figure 4: The Structure Diagram of Solar-powered

The type of DTU module is USR-GPRS232-701, produced by Jinan USER Technology Co., Ltd. It has the features of wide power supply range from DC 5V to 18V, supports TCP/UDP protocol transmission, RS232 serial communication interface. All DTU modules work on SerialNet in this system.

2.3 Solar power supply module

In order to solve the energy supply problem, we proposed a supply system based on solar energy, which consists of solar modules, solar controller, Panwar NL et al. (2011) reported an option for renewable and sustainable farming. With solar cell, solar energy was collected and stored in lithium battery to provide power supply for the system. The solar module is the core of solar energy power supply system, which puts the sun's radiation energy into electricity and store up or pushes load work, solar controller is used to control the whole module working condition. The Structure Diagram of Solar-powered Module is shown in Figure 4.

3. The hardware circuit design

3.1 The terminal node circuit design

Terminal node circuit includes acquisition, storage, and upload of soil moisture data. The signal output from the soil moisture sensor TDR - 3 is transmitted to one of the analog channels of microcontroller by conditioning circuit. Microprocessor communicates with wireless RF module by serial communication interface of TTL level, SPI serial communication protocol is used to communicate and complete the sending and receiving data between microprocessor and ferroelectric memory, interface circuit between them is also very simple, pin P1.5 of Microcontroller is connected to pin SI of FM25256, P1.6 is connected to pin SO of FM25256, pin P1.7 is connected to pin SCK of FM25256, part of the interface circuit is shown in Figure 5.

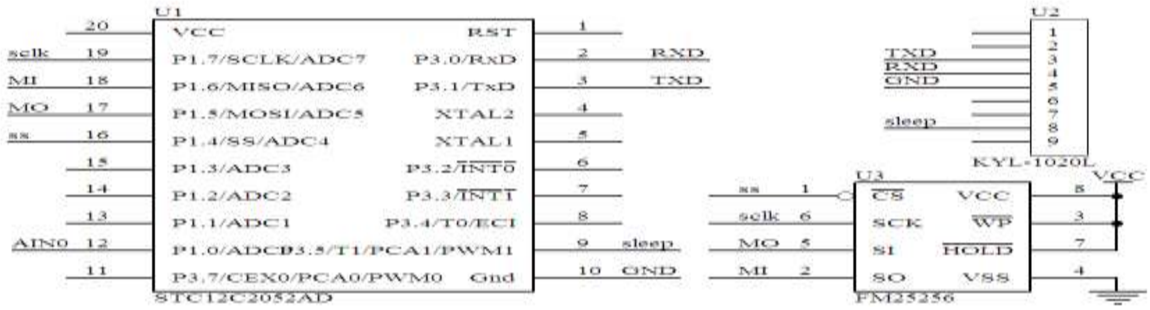

Figure 5:Terminal node circuit

3.2 The coordinator circuit design

Wireless RF module connects to DTU module through a RS232 interface in the coordinator node. The connection of RF module and DTU is shown in Figure 6.

4. Software

4.1 The software design of microcontroller

The software design of microcontroller has three tasks.
(1) Collect field data of soil moisture.
(2) Control solenoid valve turn-on and turn off, so as to control irrigation time, Robert W. Coatest et al. (2013) reported irrigation valve control.
(3) Control terminal RF module to send real-time data to the coordinator.
Software flow frame of the microprocessor is shown in Figure 7.

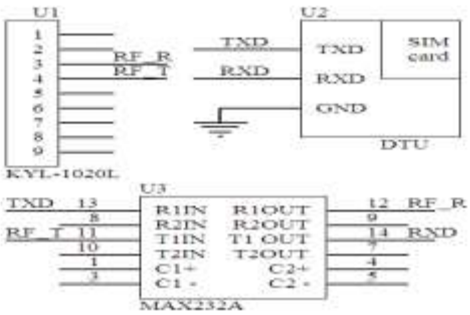

Figure 6: The connection of RF module and DTU

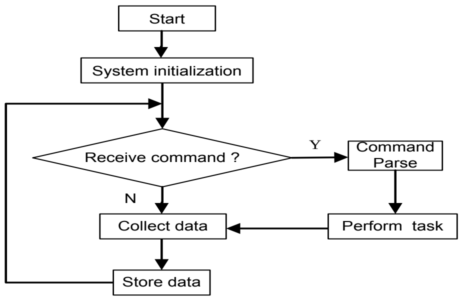

Figure 7: Software flow frame of microprocessor

4.2 Management software design of upper computer

According to the overall requirements of the system, upper computer software need to complete two tasks, on the one hand, monitoring center communicate with the test terminal via the GPRS network, on the other hand complete database management, the software provide a visual interface, can show the real-time parameters of soil of each monitoring point. Farid Touati et al. (2013) reported irrigation needs can be predicted from the data.

Users can query the history database, view the historical record and statistical curve of the crop growth environment information, and understand the comprehensive monitoring information clearly with the application of the software. The software function diagram of upper machine is shown Figure 8.

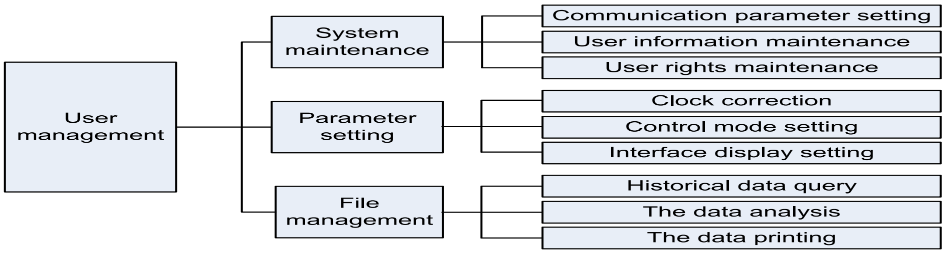

Figure 8: Software function diagram of upper

5. Experimental results

We select two terminal node experiment, one soil moisture is set in 30% and another soil moisture is set in 35%, both probe were embed for the depth of 15 cm, The experimental results showed that this system can monitor accurately soil moisture information, and by the automatic irrigation system can open and close the magnetic valve on time, so as to maintain appropriate range of soil humidity.

Table 2: Test data

Time	Node 1		Node 2	
	Soil moisture	Valve state	Soil moisture	Valve state
10:00	25.4	1	25.6	1
10:10	26.2	1	26.8	1
10:20	28.3	1	30.3	1
10:30	30.1	0	33.1	1
10:40	31.4	0	37.4	1
10:50	32.4	0	41.4	0
11:00	31.5	0	42.5	0

6. Conclusions and future work

This system gives full play to the DTU and wireless radio frequency module respective advantages and enhances the overall performance of the system. The application of this system not only reduces the operation cost, but also improves the system scalability, so the DTU and wireless RF module as a new generation of wireless network schemes will have broad application prospects.
The movement of soil moisture is very complex that influenced by many factors such as, weather element, soil characteristics and crop growth. With the application and popularization of this system, the next step will monitor meteorological conditions, the physical properties of the soil, crop species and growth condition, so as to realize the precise control of water-saving irrigation.

Acknowledgments

This work was supported by the science and technology research guidance project in Baoding (No.15ZN008 & No.15ZN012 & 13ZG003 & No.14ZG033).

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