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Araştırma Makalesi Research Article

WIRELESS SENSOR NETWORK BASED REMOTE DRIP IRRIGATION SYSTEM

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Keywords
Drip Irrigation System,
Wireless Sensor Network,
Zigbee,
Solar Energy.

Abstract
From past to present, different methods have been used for agricultural irrigation systems. Among these, drip irrigation system is more efficient than the others. In drip irrigation system, wireless sensor network is proposed to provide optimized water supply. On the other hand, zigbee has been recently used for remote irrigation systems. In irrigation system, majority of electrical energy is consumed by the pump motors. Therefore, electricity derived from solar energy is important for the economy of our country for the evaluation of cultivated land in settlements where there are no electricity transmission and distribution and far from the city center. In this study, remote controlled and solar powered based drip irrigation system with using wireless sensor network is carried out. In the system, there are two dripping system line and each dripping system line has a sensor and a valve module. These modules and system are controlled by a main module. Moreover, energy of these modules are provided by solar panels and they are communicated with each other via wireless sensor network. The control of the drip irrigation system is provided by the Android interface. Also, the system can be controlled manually or automatically with android interface via SMS.

KABLOSUZ SENSÖR AĞ TABANLI UZAKTAN DAMLAMA SULAMA SİSTEMİ

Anahtar Kelimeler
Damlama Sulama Sistemi,
Kablosuz Sensor Ağı,
Zigbee,
Güneş Enerjisi.

Öz
Geçmişten günümüze tarımsal sulama sistemlerinde farklı yöntemler kullanılmıştır. Bunların arasında, damlama sulama sistemi diğer yöntemlere göre daha etkili ve verimlidir. Damlama sulama sisteminde, kablosuz sensör ağları optimize su temini için kullanılırken, zigbee teknolojisi uzaktan damlama sulama sistemleri için kullanılmaktadır. Ayrıca, sulama sistemlerinde pompa motorları elektriğin büyük bir çoğunluğunu tüketmektedir. Bu nedenle, güneş enerjisi ile elde edilen elektrik, elektrik iletim ve dağıtımının olmadığı ve şehir merkezine uzak olan yerleşim yerleri için önemlidir. Yapılan çalışmada, uzaktan kontrollü, güneş enerjisi tabanlı ve kablosuz sensör ağlarının kullanıldığı damlama sulama sistemi uygulaması gerçekleştirilmiştir. Sistemde, iki damlama hattı olup, her bir hat sensör ve valf modülün sahiptir. Bu modüller ve sistem bir ana modül tarafından kontrol edilmektedir. Ayrıca, bu modüllerin enerjisi güneş enerjisi kullanılarak elde edilmekte olup, birbirleri ile kablosuz sensör ağı üzerinden haberleşmektedir. Damlama sulama sisteminin kontrolü Android arayüz üzerinden sağlanmaktadır ve sistem manuel ve otomatik olarak kontrol edilebilmektedir.

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1. INTRODUCTION

In the world, food demand is increasing in proportion to the population growth. In parallel with this, the dependence on the agricultural sector has increased (Nikolidakis vd., 2015). Agricultural sector uses the majority of freshwater resources. The use of freshwater has increased significantly due to the increase occurred in this sector. In addition, water pumps used in agricultural irrigation systems consumes a large amount of electricity. For this reason, need of freshwater and energy are the two most important problems at the present time (Dursun ve Özden, 2014; Dursun ve Özden, 2015).

From past to present, various methods have been tried in order to get the best yield in agricultural irrigation. In classical irrigation system, an equal amount of water is applied to the plants and an excessive amount of water is used. Giving an excessive amount of water to plants causes more energy consumption. Moreover, it increases salinity of soil and causes the decay of the roots of the plants. These disadvantages of classical irrigation system can be corrected using solar energy based drip irrigation system (Dursun ve Özden, 2015; Navarro-Hellín vd., 2015).

In drip irrigation system, water is slowly dripped to the roots of the plants through narrow tubes and valves. Thus, the supplied water passes directly to the soil without evaporation and the best efficiency can be achieved with the least amount of water. Recently, solar powered drip irrigation systems have become widespread. However, the high initial installation cost of solar energy systems hampers the widespread use of these systems. Therefore, reduction of energy consumption and losses in the irrigation system is important in order to reduce the initial installation cost of solar system (Dursun ve Özden, 2014; Dursun ve Özden, 2015; Agrawal ve Singhal, 2015).

With the development of wireless communications, there is a growing interest in sensor based applications in order to reduce the use of freshwater in irrigation systems. According to the information received from the sensors used in the system via the wireless network, the areas to be irrigated are determined and the water flow is controlled. This is done by switching valves into open or closed positions based on the information received from the sensors (Patel vd., 2011;Dursun ve Özden, 2011). The communication between the sensors and the valve can be wired or wireless. However, compared to wired communication, wireless communication is advantageous with features such as lack of cable and maintenance cost, being portable and easy installation. With the spread of wireless communication, various controllers and protocols such as microprocessors, field programmable gate arrays (FPGA), Bluetooth, global system for mobile communications (GSM) and general packet radio service (GPRS) have started to be used (Dursun ve Özden, 2015).

There are studies in the literature about solar energy drip irrigation system. In some irrigation system applications, the data from the sensors are transferred using the ZigBee and the energy requirement of the system is provided by solar energy (Rasin vd., 2009; Shuwen ve Changli, 2015). In another study, RF is used to transfer data in the irrigation system (Dursun ve Özden, 2015). In another study, the data is transmitted to the web interface using the GPRS module in the application of automatic irrigation system (Gutiérrez vd., 2014). Moreover, ZigBee is used to create a wireless sensor network (Gutiérrez vd., 2014; Nisha ve Megala, 2014).

In this study, remote controlled drip irrigation system was realized with Arduino based modules. Arduino-based modules communicated with each other over the land via the sensor network. In the system, the ZigBee was used for communication between the sensors and modules. System can be controlled manually and automatically via GSM / SMS line with android device interface. In automatic operation, the program running on the main module controlled the irrigation system by comparing the humidity values required for the plant with data received from the soil moisture sensor. The energy of the modules used in the system was provided by solar panels.

This paper is organized as follows. In section 2, drip irrigation and the main system components are mentioned. In section 3, irrigation system operation are explained in detail.

2. DRIP IRRIGATION SYSTEM

In system, there was two separate drip system line. Each drip system line had a sensor module and a valve module. There was a main module which provides control of these modules and the system. The messages sent from the Android program were sent to the sim card in the main module. The main module received and operated the message. According to the result of the operation, it was determined that the system will operate in automatic or manual mode. In the system, ZigBee, sensors, microcontrollers and solar panels were used. The communication characteristic of the system is shown in Figure 1.

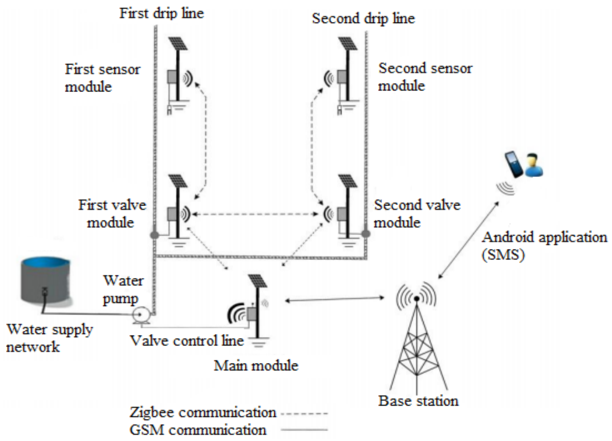

Figure 1. The communication characteristic of the system

2.1. Wireless Sensor Network and ZigBee

With rapidly growing technology, the search for a wireless system has come to the forefront between the structures on the land in order to prevent cable crowd on agricultural land. With respect to the wired networks, wireless networks have advantages such as no cable crowds, dynamic networking, low cost and easy deployment. In general, the short-range wireless scene is currently held by four protocols: the Bluetooth, ultra-wideband (UWB), ZigBee, and Wi-Fi. They are corresponding to the IEEE 802.15.1, IEEE 802.15.3, IEEE 802.15.4, and IEEE 802.11a/bg standards, respectively. Recently, ZigBee is preferred to other protocols with features such as maximum signal speed, frequency band width, range, and low energy consumption (Lee vd., 2007; Kim vd., 2008; Kalaivani vd., 2011; Nisha ve Megala, 2014; Navarro-Hellín vd., 2015). In addition, a GSM module has been used for remote communication of the system. The system can be controlled manually or automatically (DSS) via GSM / SMS line.

With the recent advances in micro electro-mechanical systems technology, wireless communications, and digital electronics, the design and development, of low-cost, low power, multifunctional sensor nodes that are small in size and communicate untethered in short distances have become feasible. The ever-increasing capabilities of these tiny sensor nodes, which include sensing, data processing, and communicating, enable the realization of wireless sensor network (WSNs) based on the collaborative effort of a large number of sensor nodes (Akyildiz ve Vuran, 2010). In this system, the sensor network has a soil moisture sensor, humidity and temperature sensor, a rain sensor and a light intensity sensor.

2.2. Arduino

In the system, Arduino Mega 2560 and Arduino Uno R3 are used as microcontroller. Arduino Mega 2560 R3 is available in the main module. ZigBee and GSM shields providing communication of system are on the Arduino Mega 2560. In addition, the Arduino Uno R3 card is used in sensor modules and valve modules. On Arduino Uno R3, there is ZigBee shields. In this way, Arduino cards in each module in the system receive and process data from serial ports and control their inputs and outputs. In Figure 2, interior of valve module and main module is shown. Table 1 shows the component list of valve module and main module.

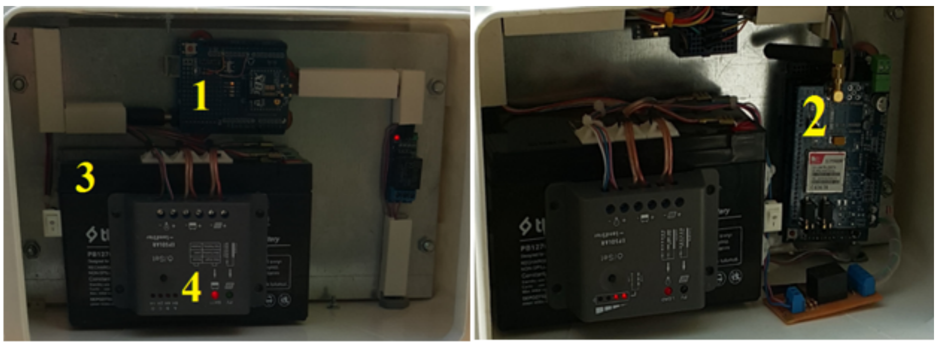

Figure 2. Interior of (a) valve module, (b) main module

Table 1. Component list of valve module and main module

Number	Module Name
1	Arduino Uno R3
2	Arduino Mega 2560
3	Battery
4	Charge regulator

2.3. Solar Power System

In agricultural areas where there is no electricity, alternative energy sources are used for the power requirements of the system modules. In this study, solar power system consists of PV module, battery and charge regulator, which are used for the power requirements of the system modules (Gutiérrez vd., 2014; Nisha ve Megala, 2014). Solar power system is shown in Figure 3.

A photovoltaic (PV) cell is an electrical device that converts the energy of light directly into electricity. The equivalent circuit model of PV cell is shown in Figure 4. The voltage-current characteristic equation of a PV cell is given in Equation (1).

$$I = I_{PH} - I_O[\exp(\frac{q}{kTA}(V + IR_S)) - 1] - \frac{V + IR_S}{R_{SH}} \quad (1)$$

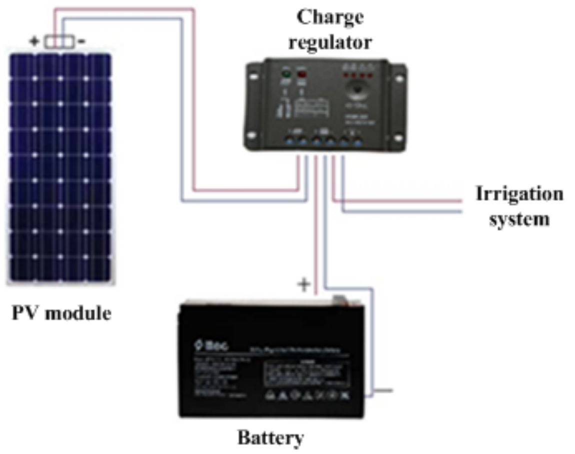

Figure 3. Solar power system

In Equation (1), I_{PH} is a light-generated current, I_O is reverse saturation current of the diode, T is the cell's operating temperature, k is the Boltzmann constant (1.381x10^{-23} J/K), q is the electron charge(1.602x10^{-19} C), A is diode ideality constant (Tsai vd., 2008; Rahim vd., 2013; Kiriş vd., 2016; Bingöl ve Özkaya, 2018).

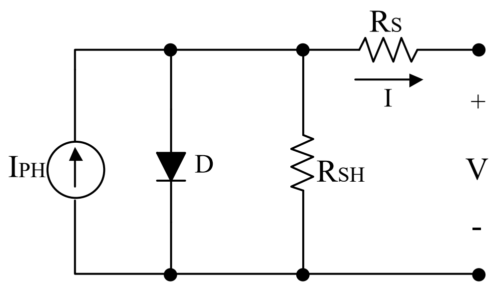

Figure 4. The equivalent circuit model of PV cell

The output power of PV cell is quite less. Therefore, to produce desired output power, PV cells are connected in a module of series and parallel configuration. The equivalent circuit model of PV cell is shown in Figure 5. The voltage-current characteristic equation of a PV cell is given as

$$I = N_P I_{PH} - N_P I_O[\exp(\frac{q}{kTA}(\frac{V}{N_S} + \frac{IR_S}{N_P})) - 1] - \frac{\frac{N_P}{N_S}V + IR_S}{R_{SH}} \quad (2)$$

where N_P is the number of PV cells connected in parallel and N_S is the number of PV cells connected in series (Tsai vd., 2008; Rahim vd., 2013; Bingöl ve Özkaya, 2018). PV module parameters used in the system is given in Table 2.

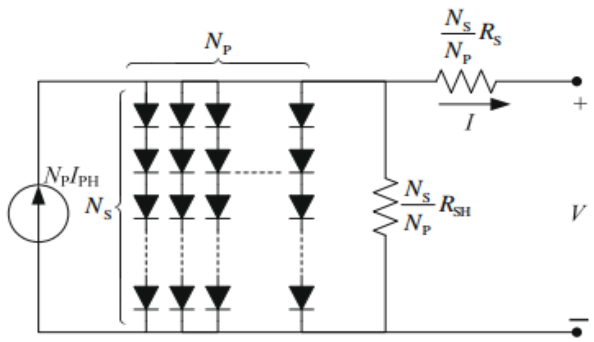

Figure 5. The equivalent circuit model of PV module

Table 2. PV module parameters used in the system

Parameter	Label	Value
Maximum power	P_{max}	10 Watt
Maximum power point voltage	V_{mpp}	17 V
Maximum power point current	I_{mpp}	0.59 A
Open circuit voltage	V_{oc}	21.5 V
Short circuit current	I_{sc}	0.64 A

The purpose of using the battery is to prevent the energy losses of modules and to provide an uninterrupted operation. For each module, Ttec 12V/7Ah dry battery and EP Solar LS0512 12V / 5A charge regulator are used. The purpose of using the battery is to prevent the energy losses of modules and to provide an uninterrupted operation.

2.4. Interface of System

The interface of the irrigation system was designed using the MIT App Inventor program. The interface consists of six screens. These are login screen, decision screen, control screen, information screen, rain sensor activation screen and clock setting screen. In Figure 6, sub screen of android interface which is (a) login screen, (b) decision screen, (c) control screen, (d) information screen, (e) rain sensor activation screen and (f) clock setting screen are shown. The login screen is the security screen which has the user name and password entry. On the decision screen, there are control screen, system information screen, rain sensor activation screen, time setting screen, emergency stop, back and close program button. On the control screen, two separate drip systems can be controlled and the system can be taken to automatic mode. Also, there are "turn on" and "turn off" buttons for each dripping system. On the information screen, the measured values which are temperature, ambient humidity, raw lever, rain status, amount of radiation, soil moisture value for each dripping system line can be displayed. On the rain sensor activation screen, there are "active" button for activation of rain sensor and "passive" button for deactivation of rain sensor. On the clock setting screen, the clock is entered and then this information is sent to the system. Then, the opening and closing times of the drip system are entered and necessary drip opening and closing operations are performed automatically (Bayram, 2016).

3. IRRIGATION SYSTEM OPERATION

In the system, the messages (SMS) sent from the Android program are sent to the sim card in the main mode. The main module receives and processes the SMS. As a result of the work done, it is determined that the system will operate in automatic mode or manual mode (Bayram, 2016).

When the system operates in manual mode, no data is sent to the sensor module where the humidity sensor is located and the sensor module waits in sleep mode. In manual mode, only valve opening and closing operations are performed. Therefore, it is communicated with the valve module. There is a solenoid valve at the output of the valve module. If any valves are opened and closed manually from the main module, the valve modules communicate wirelessly over the ZigBee and opening and closing operations are performed. For feedback, information that the valve is opened or closed is sent to main module from the valve module and Android program are informed with SMS (Bayram, 2016).

Figure 6. Sub screen of Android interface (a) Login screen, (b) Decision screen, (c) Control screen, (d) Information screen, (e) Rain sensor activation screen, (f) Clock setting screen

When the system runs in automatic mode, firstly the humidity value entered in the Android program or the moisture value of the selected plant and information to pass to automatic mode are reported to the main module via SMS. The main module processes incoming data. Data is transmitted wirelessly to the valve module or modules which will go into the automatic mode via ZigBee. The valve module transfers the moisture information and information that passed to the automatic mode to the sensor module. In other words, the moisture information is sent to the sensor module wirelessly via the valve module. The sensor module and the valve module passed to the automatic mode inform the main module and the information passed to automatic mode is transferred to the android program as SMS. The sensor module continuously compares the moisture information coming from the valve module to the measured moisture information coming from the soil. As a result of the comparison of the moisture information, the sensor module sends to open or close valve information to the valve module (Bayram, 2016).

The general view of the system is shown in Figure 7, and the view of the drip irrigation system is shown in Figure 8. Table 3 shows the list of the modules used in the system shown Figure 7. Figure 9, Figure 10 and Figure 11 respectively shows the flowchart of the android program, flowchart of the first sensor module and flowchart of the first valve module.

Table 3. List of the modules used in the system

Number	Name of Module
1	Main Module
2	Sensor module for first drip system
3	Valve module for first drip system
4	Sensor module for second drip system
5	Valve module for second drip system

Figure 7. General view of the system

Figure 8. The view of the drip irrigation system

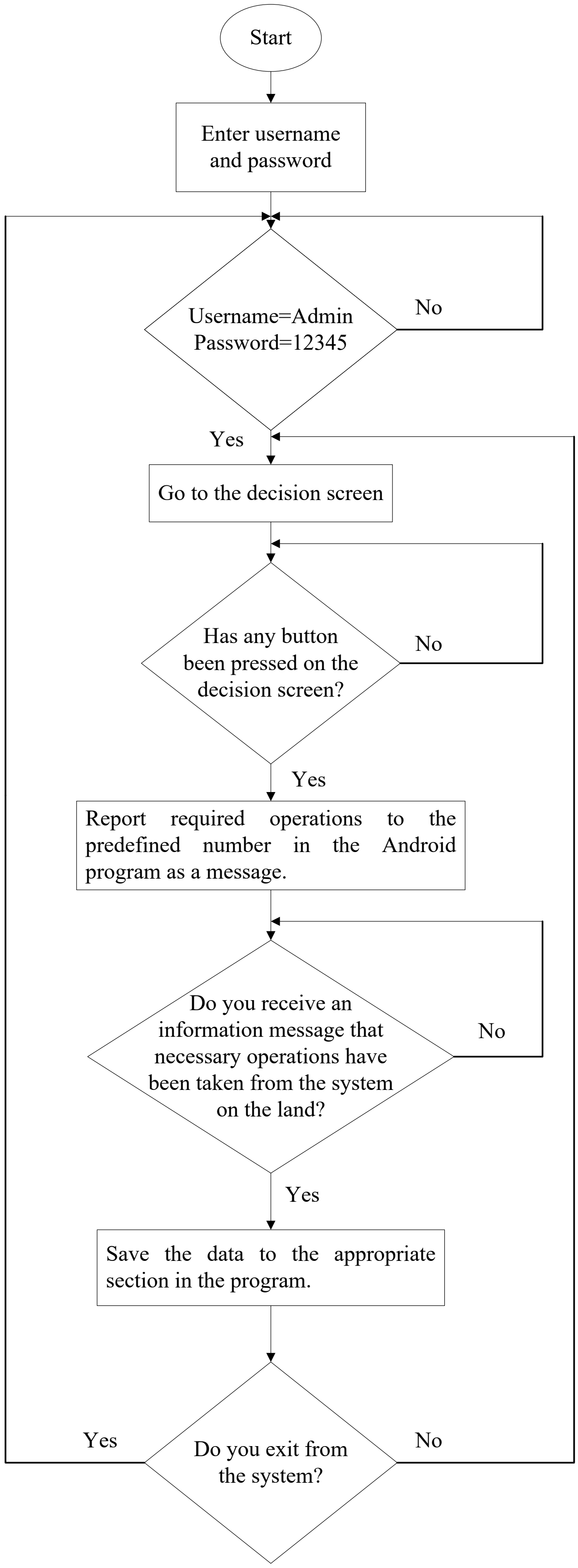

Figure 9. Flowchart of the android program

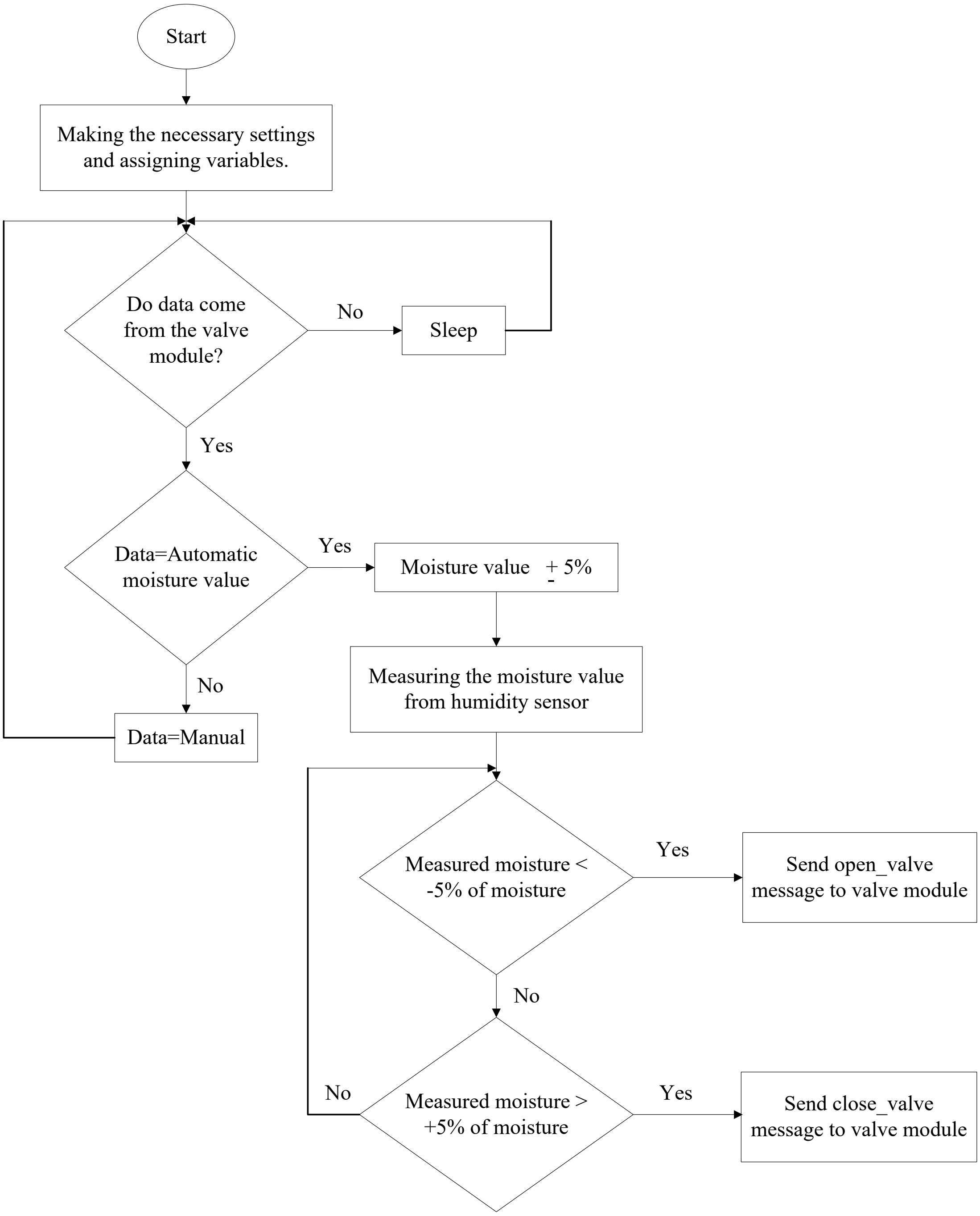

Figure 10. Flowchart of the first sensor module

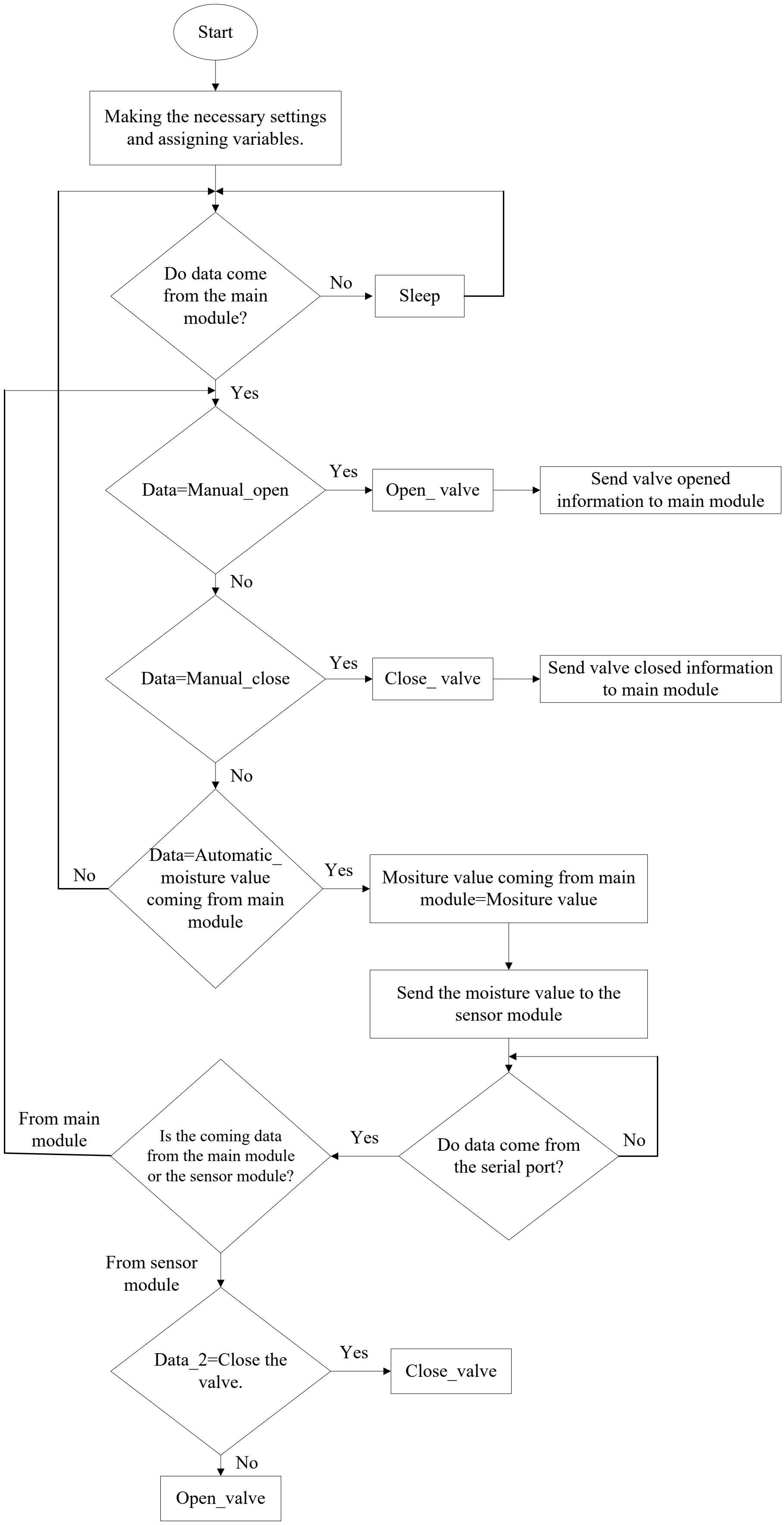

Figure 11. Flowchart of the first valve module

4. CONCLUSION

Nowadays, it is aimed to provide the best efficiency with minimum water use in all areas with the reduction of clean water. In addition, energy efficiency in irrigation systems is one of the most important issues. Studies on energy efficiency and remote control applications in agricultural irrigation systems are increasing day by day. In this study, remote controlled solar powered drip irrigation system using wireless sensor network was realized. ZigBee was used in the system to provide wireless communication between sensors and modules. The system had wireless sensor network so, it provides a cost advantage, ease of installation and easy portability. In addition, the energy requirement of the water pumps used in the system was provided by the electric energy produced by the solar panels on each module. The battery was used to keep the system running when there is no sunlight. Thus, unnecessary energy consumption was avoided.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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