Study on Precision Water-saving Irrigation Automatic Control System by Plant Physiology

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Abstract—Olympic Games in 2008 is not only a world sports event, but also a great opportunity to show our current level of economic development and modern science and technology strength. Precision water-saving irrigation automatic control system by plant physiology this paper described is one of the Olympic Games facilities projects, which takes standards of water plant physiologically need and soil water content as the basis. Through the combination of independent research and development of irrigation monitoring controller and wireless data transmission, implement a drip irrigation, sprinkler irrigation, micro-irrigation, and low-pressure pipelines, such as different modes of irrigation automatic control. On this basis, the system monitors by GSM remote wireless communication make all irrigation incidents automatically enter into the database, and generate a variety of reports to the irrigation data for statistical analysis. This paper describes system structure on two aspects of hardware and software design, it is characterized by a flexible mode of operation, reliable control and data transmission, low-cost, remarkable water-saving effect. National Road precision water-saving irrigation project's preliminary trial implies that this new type of precision water-saving irrigation control system with independent intellectual property rights has a higher value for promotion.

Index Terms—soil water, water-saving irrigation, automatic control

I. INTRODUCTION

Precision water-saving irrigation automatic control system by plant physiology is researched and developed independently by Beijing Forestry University including BLY（type of plant vitality analyzer）plant viability analyzer, BD-1 soil water sensor, irrigation monitoring controller, system monitor and upper monitor computer and related software. System structure is shown in Fig. 1. The system can be applied to actual greenbelt irrigation control, also be used to plant drought-resistance test, precision irrigation, and other related scientific experiment. Main function includes:

- BLY plant viability analyzer’s detection of plant vigor on the nature of activities of plant life; real-time detection of dynamic changes of water plants need in the drought process.
- Real-time detection of soil water content (volume water content).
- The estimates of best irrigation for greenbelt and automatic control of sprinkler irrigation system.
- Control plant roots soil water to near settings in a long time.

II. SYSTEM PRINCIPLE AND IRRIGATION CONTROL STRATEGY

A. Biological basis

Experts’ study show that: drought (moisture deficit) and high temperature are two main environmental stress factor in Chinese northern region during plants growing season. Another scholars’ study shows that: The impact on different soil water handling on stem weight, and root weight, total biomass is notable, plant leaves relative moisture content and water consumption volume per plant decrease with the reduction of soil water, only when soil water content is higher

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than a certain threshold value, the plants could survive, higher soil water content could ensure greater ownership of plant biomass. However, when soil water content is too high, it will not only cause decay of the root, but also a waste of water resources at the same time, and as a result of too much irrigation, water infiltration will take away large fertilizer, which causes a waste of fertilizer, pollution of groundwater resources. Therefore, controlling soil water content near root of plants in a certain range between plant survival threshold value and plant water requirement with the largest biomass could ensure a large number of water-saving and plant’s appreciation. That is the biological basis of the control system.

B. System Principle

For different plants, different terrain, different seasons, system get plant water demand information by BLY plant viability analyzer, through soil water sensor’s acquisition of two different depths of soil water information, and transmit information to irrigation monitoring controller or computer to analyze through system monitor, which make irrigation decision and control start-up and shutdown of the sprinkler irrigation system, it could make sure of adequate soil water of plant roots and meet the demand of plant growth, and enable substratum soil water stable near a default value, avoid excessive irrigation which result in a waste of water resources, prevent excessive irrigation away fertilizer and the pollution of underground water resources.

When the detection value of BLY plant viability analyzer is lower than set value information of plant water demand, meanwhile upper soil water sensor detection value is lower than upper soil water setting, irrigation monitoring controller will send start-up signal to corresponding valve, activate nozzle and start irrigation work. At the same time, substratum soil water sensors real-time detect soil water information, when its measured value and substratum settings of soil water content’s deviation is over 5%, Irrigation monitoring controller will send stop signal to corresponding valve, the nozzle will close, irrigation work is done. System principle is shown in Fig.2.

C. System irrigation control strategy

The function of the system is carried out by irrigation area, round irrigation area and round irrigation area set. Irrigation area is the smallest control unit of system, including a number of soil water information acquisition points, plants water demand information acquisition point and a number of electromagnetic valve. System control electromagnetic valve in the irrigation area in accordance with the soil water content information of irrigation area and plant water demand information. So that soil water of the irrigation area is stable near the default value. Default value of soil water content in various irrigation area are different as a result of different types of vegetation.

Default value of soil water content in the same irrigation area is different as a result of plant growth stage and the changes of seasons.

Round irrigation area composes of a number of irrigation areas, and equips with a irrigation monitoring controller. System considers round irrigation area as unit to make irrigation strategy, i.e. round irrigation areas in the same irrigation area adopt the same irrigation strategy. Irrigation strategies of different round irrigation areas are different because of the difference of topography and soil type.

When necessary, if round irrigation areas compete with water resource and irrigation systems in round irrigation area are related to each other, round irrigation set may be composed of several round irrigation areas to realize more complicated control.

Control strategy at every level is carried out by the corresponding irrigation monitoring controller. According to system status parameters, irrigation monitoring controller acquires plant water demand information, soil water content, does the estimation of irrigation and controls start-up and shutdown of irrigation system with automatic mode, semi-automatic mode and manual mode three working mode.
• Automatic mode: This mode includes automatic control and time control, users can choose any one. In automatic control mode, users only need to set corresponding status parameters, system can automatically complete soil water acquisition, data analysis and control of irrigation system without manual intervention. However, in the time control mode, the users need to set the start time and stop time for each valve, according to the time table, system controls irrigation systems automatically.

• Semi-automatic mode: In this mode, users need to operate upper monitoring computer to complete data acquisition and valve, automatic mode settings no longer work.

• Manual mode: System could be switched to manual mode by control switch on cabinet knobs, the system can normally acquire soil water content information right now, but can not control irrigation system, need manual control electromagnetic valve.

D. Division principle of system control round irrigation area

Division principle of round irrigation area

- Water exclusive principles: water resource of round irrigation area is unique as far as possible, and not shared with other round irrigation areas.

- Terrain principle of unanimity: the terrain in round irrigation area is consistent as far as possible to make irrigation strategy unify easily. In the circumstances of inconsistent terrain, adopt corresponding irrigation strategy of main terrain. When the area of plains equal to the slopes, adopt slope irrigation strategy.

- Soil type consistent principles: soil type in the round irrigation area should be consistent.

Division principle of irrigation area

- Vegetation unifying principle: the vegetations in the irrigation area are as far as possible consistent with each other, the soil water default value is based on plant water requirements.

- Water Supply principle: when valves in irrigation area are all open, make sure that every nozzle’s water pressure is adequate.

Figure 2. The operating principle of system

Figure 3. The system hardware configuration
E. Tuning of irrigation area soil water default value

The water requirements of different plants are different, water requirement of the same plant in different stage of growth and season are also different. It is no need to have the greatest biomass for landscape plant, a certain level to watch is just good. In this principle, do a series of drought resistance estimate for plant in irrigation area, set soil water default value based on estimate results.

F. System status parameter

System status parameter is mainly parameter setting of irrigation monitoring controller, including: controller attribute, controller working time, valve open time, control area, mobile phone number setting and task setting.

- Controller attribute, including mainly mobile phone number of controller and mode of operation. Click the "setting" button at the bottom of the dialog box to complete setting.

- Controller working time, it is used to limit the time in which it is suitable to irrigate for greenbelt, system will not start irrigation outside the scope of the set time.

- Control area, it is used to set attribute for every irrigation area in the round irrigation area, including area title, sensor attribute and valve attribute. Sensor attribute includes irrigation threshold (soil water default value), the maximum and minimum alarm threshold value of soil water. In valve attribute you can change valve name.

- Valve open time, it is used to set the length of time in every irrigation area every time and minimum time interval between twice irrigation.

- Task setting, it is used for the time control mode. Every day you can set seven tasks of valve’s start and stop, one week one cycle.

- Mobile phone number setting, "target mobile phone number," refers to phone number of upper monitoring computer, the "mobile phone number for alarm," is used to set the staff’s phone number, system can notice the staff at the first time.

III. THE DESIGN OF SYSTEM

A. The design of system hardware

For national Olympic projects - National Road precision water-saving irrigation project, an area of eight hectares, in accordance with different terrain, different plant, it is made up of 54 irrigation areas, 6 round irrigation areas and 2 round irrigation area groups. The system needs to control 89 electromagnetic valves, 1000 nozzles, 4000 irrigation emitters; 2 BLY plant viability analyzers, 98 BD-1 soil water sensors, 6 irrigation monitoring controllers and 3 system monitors. It is shown in Fig. 3.

The system is made up of control cabinet unit and upper control computer unit.

The one is that, irrigation monitoring controller reads plant physiologically water requirements information and soil water information BLY plant viability analyzer and BD-1 soil water sensor provide, make irrigation decision in irrigation monitoring controller, judge the situation of plant water demand, if plant needs water, and soil water is below the threshold value, the orders (activate nozzle and do the sprinkler irrigation) will be sent to the electromagnetic valve.

The other hardware work component is that, irrigation monitoring controller read plant physiologically water requirements information and soil water information BLY plant viability analyzer and BD-1 soil water sensor provide. First, messages will be delivered to system monitor, and then to the upper control machine through GSM remote wireless communication. The upper machine makes irrigation decision, carries out sprinkler irrigation. Upper control machine also do the work of setting BD-1 soil water sensor parameter, soil type calibration in the system application environment and other system management.

B. Design of software

For control cabinet unit, system uses multi-threading technology in the system. It is divided into three threads.

One thread mainly is used to monitor RS-485 bus network working conditions composed of irrigation monitoring controller, BD-1 soil water sensor and electromagnetic valve. Irrigation monitoring controller real-time reads BD-1 soil water sensor information, and compares with the threshold value of irrigation, when soil water is lower than threshold value of irrigation, irrigation monitoring controller sends start-up signal to electromagnetic valve to trigger the sprinkler to carry out irrigation to plant.

Another thread is used to monitor RS-485 bus network working conditions composed of six irrigation monitoring controllers and three system monitors. System coordinates with the work following irrigation principle.

Third-line is used to control that two main threads ‘s security, when anyone of these threads doesn’t work, the thread will do repairing work or initialization work, after the failure of repairing work or initialization work, issues alarm signal to inform staff to manually repair to make sure of safe operation of the whole system.

For upper control computer unit, apart from the multi-threading technology, System has also adopted component technology.

During system operation, do data exchange by driver and external equipment. Each driver is a component object. In this way communication program and software make up a complete system to make sure of high efficiency of operational system.

Design of foreground control software, control software is made up of three parts: art display control interface, alarm display interface, keypad interlocked. The whole control screen adopts animation design, it is convenient and intuitive to show the whole system processes with animation design.
Alarm Display Interface marks 89 electromagnetic valves, 1000 BD-1 soil water sensor states. If alarm signal (water demand signal) generates, alarm display interface will remind operators to operate. If the system is running in automatic mode, it will automatically send a control signal to open corresponding equipment to begin (to stop). irrigating, enter into open (off). Information of equipment automatically to the database at the same time.

Communication Module Design.

Do data exchange through driver and external equipment. Each driver is a component object.

History Database’s Design system uses Microsoft Access database and Microsoft's Odbc database engine. All equipment operations are automatically entered into the database, and automatically be formed irrigation statements. Database will automatically records change time, date, serial number of each electromagnetic valve’s state, operator’s mobile phone number and the corresponding BD-1 soil water sensor information, which provide a basis for scientific analysis and irrigation for the future.

IV. EXPERIMENT

The national Olympic projects - National Road adopt precision water-saving irrigation automatic control system by plant demand which this paper describes. According to the plant (turfgrass) characteristics, BLY plant viability analyzer will make plant water demand information in the control software in advance, install two BD-1 soil water sensors respectively in the ground 8 cm and 20 cm, real-time monitor soil water content. The valve will be activated threshold set at 27 %, and stop threshold settings at 18%. Control result obtained is shown in Fig.4.

V. CONCLUSION

Through National Olympic projects - successful application of National Road precision water-saving irrigation projects, test the reliability of the system design, safety and scientific. BLY plant viability analyzer, BD-1 soil moisture sensor, irrigation monitoring controller, system monitor and upper monitor computer hardware and related software have completely independent intellectual property rights. They control electromagnetic valve, realize the drip irrigation, sprinkler irrigation, micro-irrigation, and low-pressure pipe irrigation methods such as the automation of irrigation mode, achieve the purpose of a highly efficient precision. It is a new way of thinking of implementation irrigation issue in solving China's serious water shortage situation.

REFERENCES