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Research on Irrigation System Modeling and Group Control Strategy in Agricultural Planting Base

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Abstract:

In order to improve irrigation efficiency and achieve high output and benefit of crops with less irrigation water, this paper introduces the specific situation of the planting base. Then, it gives the model of the irrigation water volume and estimates the daily irrigation water consumption. In addition, according to the distributed characteristics of pump wells in the base, the group control strategy of using wireless communication network to complete the main control room and 9 distributed pump wells is designed. Practice has proved that the effect of water-saving irrigation is obvious.

Keywords*: Irrigation system, Modeling, Group control strategy.*

I. INTRODUCTION

Drought and water shortage is the most prominent contradiction in contemporary and future society. Agriculture is a large water user in China, accounting for 70% of the total water consumption in China, in which, farmland irrigation accounts for 90-95% of agricultural water consumption[1]. The waste of agricultural water is quite serious. The utilization rate of farmland irrigation water is very low, with an average of only about 45%. Water conservation is not only a long-term strategy related to the sustainable development of population, resources and environment, but also an urgent task of current economic and social development[2]. Water saving irrigation is to fundamentally change people's traditional irrigation habits for thousands of years, turn the tradition of irrigating ground into irrigating crops. So, it can take promoting crop growth as the fundamental purpose, timely and appropriately carry out irrigation according to the requirements of crop growth water demand, improve irrigation efficiency, save water, and realize high output and high benefit of crops with less irrigation water[3]. Water saving irrigation has become an effective way to alleviate the waste of water resources and realize the sustainable development of agricultural water in China. The automatic control technology in water-saving irrigation is the core and key of water-saving irrigation.

Irrigation automation began in the 1930s. Before the Second World War, France developed a series of hydraulic automatic gates to implement the automatic operation of canal system and put forward a relatively complete set of automatic irrigation control methods, which opened the precedent of automatic

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irrigation. Since the 1950s, with the application and development of electronics and computer technology, the irrigation and drainage engineering automation technology controlled by electronic equipment, computer equipment and software has also developed synchronously. It has been increasingly widely used and developed in developed countries such as France, the United States and Japan and even some developing countries, in addition, the control mode has also developed from the early local control to the centralized control mode that can realize telemetry and remote control[4-6].

Some foreign advanced countries, such as the United States, Israel and Canada, use advanced electronic technology, computer and control technology tocarry out research early and become more and more mature in water-saving irrigation technology. From the earliest hydraulic control and mechanical control to the later mechanical electronic hybrid coordinated control, and then to the widely used computer control, variable structure control[7], $H\infty$ robust control[8], predictive control, neural network control[9] and fuzzy control[10], the control accuracy, reliability and intelligence of these countries are getting better and better. At present, high and new technologies such as spatial information technology, computer technology and network technology are applied to the control and management of water-saving irrigation. These technologies are the focus of water-saving irrigation research. Israel has made the most outstanding achievements in the development and application of water-saving irrigation technology abroad.

Since the introduction of water-saving irrigation technology and equipment from abroad in the 1950s, China's water-saving irrigation technology and equipment have been mainly demonstration application for a long time. In addition, some problems in design, management and equipment have not been applied in a large area, and there are fewer supporting automatic control systems. In the 1980s, especially after the 1990s, with the development of economya, the shortage of water resources and the attention of the government, water-saving irrigation has developed rapidly.

As early as 1994, Mao Shenjian and Zhang Wenge designed a fully automatic irrigation control system with 8031 single chip microcomputer as the core, which has the function of multi-channel timing control irrigation. The system is designed as a modular structure and can be combined according to different applications[11]. In recent years, there are also the "remote mobile phone wireless irrigation control system" developed by the National Agricultural Information Engineering Technology Research Center[12], the "Yunshui brand solar wireless irrigation controller" jointly developed by Wuhan Wuda Yunshui Engineering Co., Ltd. and Shanghai Bute electric company, and the "water-saving irrigation automation control system" developed by the water conservancy construction technology service center of Fujian Provincial Department of water resources. However, compared with foreign countries, the automatic irrigation control system is still very backward. Many control system products rely on imports from abroad. The imported foreign irrigation automatic control equipment is designed for the specific situation of foreign countries, without considering China's climate, terrain, crop types and other factors, which is not suitable for China's national conditions and can not give full play to its advantages.

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Therefore, it is very necessary and urgent to accelerate the development of a complete set of applicable, reliable, low-cost, high-efficiency and advanced intelligent water-saving irrigation control system suitable for China's national conditions, which is also the main direction of the development of water-saving irrigation equipment in China in the future.

II. INTRODUCTION TO AGRICULTURAL IRRIGATION SYSTEM

The irrigation system is located in a large agricultural vegetable planting base in the lower reaches of the Yellow River, covering an area of about 30000 mu. The base is located in a flat area with 9 underground water pumps, forming an irrigation network in the base. Among them, 1-8# pumps use frequency converter to control the pump motor, and 9# use directly starting the pump motor with power.

The design capacity of the irrigation system is 9000 m3 per 24 hours and the pump power of the nine pumps in the base is 18 kw. A main control room is set in the center of the base to uniformly control the pumping and irrigation of 10 wells according to the water volume requirements of different areas of the base. It can realize the networked operation of pump groups and incorporate all 9 well locations into the monitoring system. Each pump station shall include monitor and control the pressure signal, flow signal, liquid level signal and motor status. Then it uniformly summarize them to the central control room, which will make the irrigation system operate in the most reasonable state according to the water demand. It can be seen that the main control room needs to communicate with the surrounding 10 wells in real time and issue control commands to each well. After receiving the commands, each well controls the local well pump according to the requirements and feeds back the local information to the main control room. Therefore, the reliability and timeliness of the communication system are the key to the normal operation of the whole irrigation system.

III. IRRIGATION WATER QUANTITY MODELING OF PLANTING BASE

To determine the efficient irrigation system, we need establish the mathematical model of irrigation quota (total irrigation amount in growth period) and yield. Thus, we can predict the irrigation quota according to the established mathematical model and use dynamic programming to determine the efficient irrigation system. At present, the models describing crop irrigation quota and yield are mostly quadratic parabola and deformation parabola. From the relationship between irrigation quota and yield previously studied, it is found that when the irrigation amount exceeds a certain optimal irrigation quota, the yield decreases with the increase of irrigation amount. However, the fact described by quadratic parabola is inconsistent with the fact. Therefore, we try to find another mathematical model to reflect this fact.

Therefore, after a lot of data search and analysis, we decided to use piecewise function to describe the water supply yield model of irrigation base. Let the water supply function be,

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$$Y=f(x) \tag{1}$$

Y - crop yield per mu (kg)，X - total water consumption per mu (m^3)

By analyzing the composition of variable x, we get the following relationship.

$$X=X_1-X_2+X_3-X_4 \tag{2}$$

X_1 - Irrigation water, X_2- Precipitation, X_3-Water consumption affected by temperature, X_4- Water consumption affected by humidity

$$X_3=K_1\, C \tag{3}$$

C - Average temperature in the base

$$X_4=K_2\, D \tag{4}$$

D - Average humidity in the base

We take the 1# planting base as an example. Cucumber is planted in the 1# base and the specific model of irrigation water volume is constructed. We analyze several agricultural irrigation water volume models and come to the conclusion that the yield of each base has a peak. When the yield is less than the peak, the relationship between irrigation water volume and yield basically conforms to the throwing line. When the yield is greater than the peak yield, The relationship between irrigation water volume and yield basically conforms to the exponential function.

Set the peak value of irrigation water as A,

When $X<=A$, $f(x)=a_1x^2+b_1x+c_1$ (5)

When $X>A$, $f(x) = k_4 e^{-k_2x+k_3}$ (6)

Find the data to obtain several corresponding data of irrigation and yield, then fit the parabola curve through the simulation software, as shown in Figure 1.

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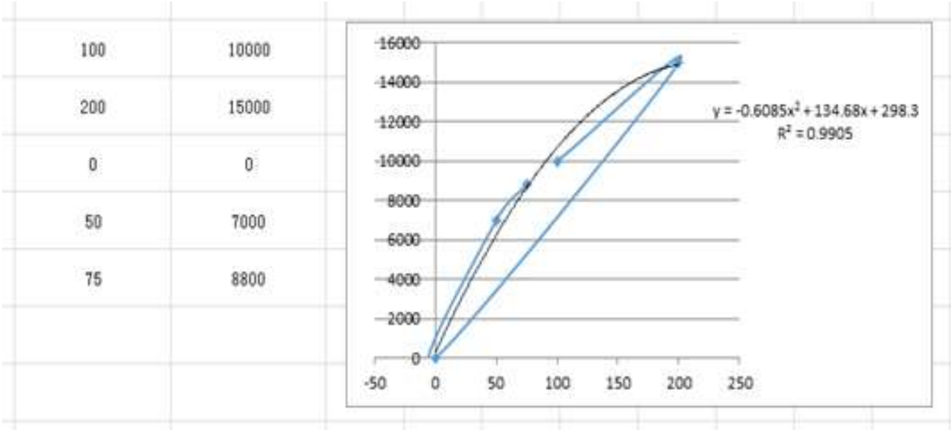

Figure 1: fitting curve between irrigation water volume and yield

From the Figure 1, we get the following formula.

$$f(x)= -0.6085x^2 + 134.68x + 298.3 \qquad (7)$$

The derivative of (7) is obtained, $f'(x) = 134.68 / 0.6085 = 221\ m^3$

Therefore, we calculate the maximum irrigation water consumption value a of 1# planting base through the model, $A = 221\ m^3$.

In this way, we can roughly estimate the daily irrigation water volume B,

$$B=A/T \qquad (8)$$

T - growth cycle of vegetables

Using the same method, we can calculate the daily irrigation water volume of 2-9# well in the planting base.

IV. IRRIGATION SYSTEM CONTROL STRATEGY

To form an irrigation system, we must first equip various hardware according to the control requirements and then connect the various components with a network. So the framework of the control system is formed. Through software programming and networking, a system that can meet certain functional requirements is established. As the wells are scattered and far away from each other, it is difficult to lay cables. We adopt wireless networking, which saves cost and improves efficiency. Therefore, the distributed measurement and control system is composed of wireless data transmission radio and multiple single chip microcomputer control units. PC is used as the upper computer.

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According to the situation of each well, for a single well pump, we use stem32 single chip microcomputer to design an independent well pump control system. The specific control system is shown in Figure 2.

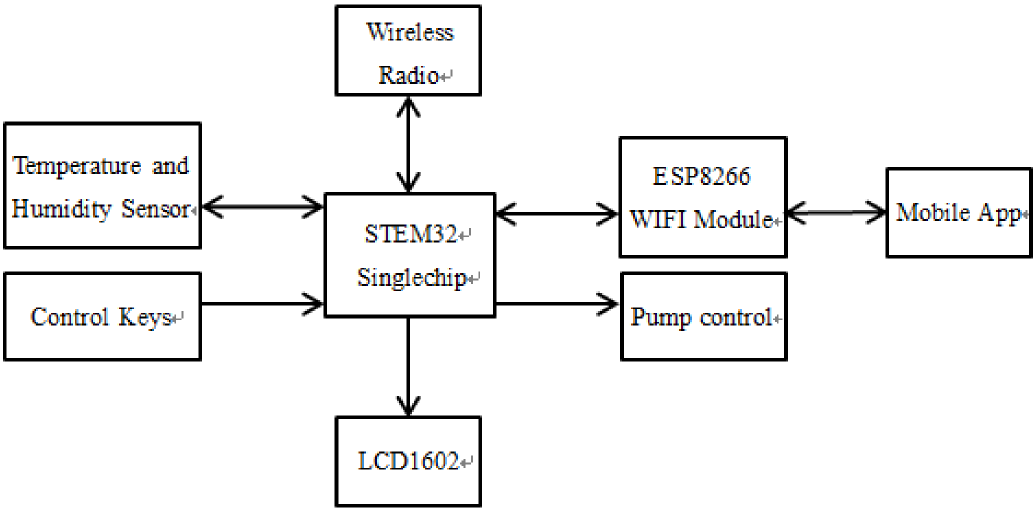

Figure 2: single chip microcomputer control system for single well

From the above control system figure, we can see that it can communicate with the wireless data transmission radio through the UART port. The radio can send local information to the main control room or receive the command information issued by the main control room to the well. In addition, the STEM32 single chip microcomputer can also collect the temperature and humidity signal of the planting base and control the start, stop and speed regulation of the water pump. The information of the single chip microcomputer system can also be connected with the user's mobile phone through the ESP8266 WIFI module. In the base area, the user can check the operation of each water pump through the mobile phone at any time.

The main control room is the control center of the whole irrigation system. The main control room is equipped with a high-performance PC, which is connected to a wireless modular data transmission radio through serial port. The communication distance can reach 15 km. Different signals from 9 well stations can be received through software programming at the PC station. The distributed well group control scheme of our water-saving irrigation system is shown in Figure 3.

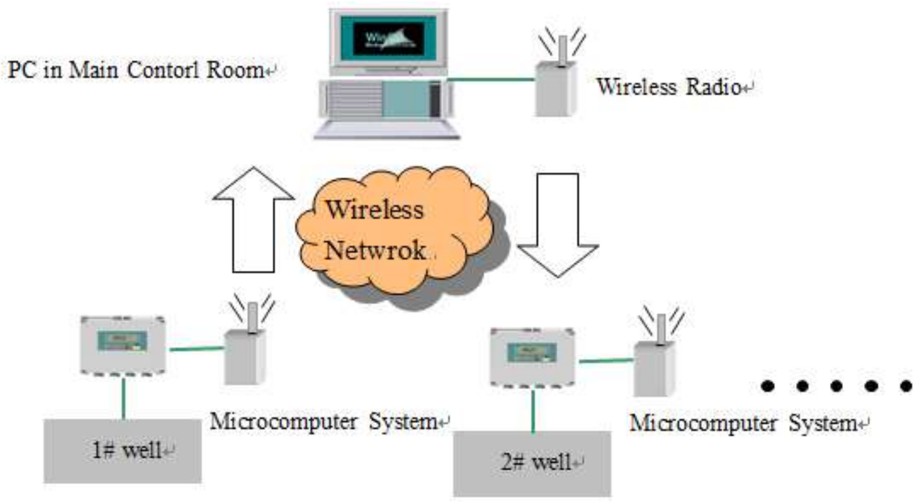

Figure 3: well group control strategy chart

V. CONCLUSION

Through the previous irrigation model, we can calculate the water demand of vegetables in the whole growth cycle. The average irrigation water per day can be estimated according to the growth cycle. According to the characteristics of different vegetable growth cycles, the irrigation water volume of vegetables in different periods is planned. A soil humidity sensor is installed in each planting base to calculate the irrigation time according to the humidity value. In case of high humidity, daily irrigation can be reduced to spare irrigation water or even no irrigation. The practice shows that the irrigation water is saved by more than 20% and the yield of vegetables is significantly improved after using the group control system.

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