Research on efficient operation of electrical control automation system based on intelligent frequency conversion regulation in agricultural water-saving irrigation

Abstract: In the context of the promotion of the concept of sustainable development, how to improve the utilization of water resources on the basis of limited natural resources to promote the efficiency of agricultural production and economic benefits, etc. is a hot issue of concern at present. In this study, a PID intelligent frequency control controller is selected to design the constant pressure water supply module of agricultural water-saving irrigation system. Then based on the air temperature and humidity and soil moisture sensors to design the environmental information acquisition module of the system, and finally combined with the design of intelligent frequency conversion agricultural water-saving irrigation control system. The results of empirical analysis show that the water consumption and energy cost of intelligent frequency conversion irrigation technology in cotton crop irrigation are much lower than that of small flow irrigation and traditional irrigation methods. It was also found that the output of cotton crop (5562.36 kg/ hm^2 and 5629.35 kg/ hm^2) was significantly higher under this irrigation technology and the average net income per hectare of output was significantly higher than the other two irrigation methods. The automatic irrigation control system designed in this paper based on intelligent frequency conversion technology greatly improves the irrigation efficiency, realizes the efficient use of water resources and high yield quality of crops, and facilitates the dynamic monitoring and management of agricultural irrigation process.

Keywords: Frequency conversion motor, PID controller, water-saving irrigation, agricultural production; economic benefits.

1. Introduction

China is a large agricultural country, the demand for water resources is great, coupled with the uneven distribution of water resources, water shortage in some agricultural cultivation areas, and the need to holistically improve the utilization of water [1]. For this reason, agricultural water-saving irrigation projects have been in the spotlight [2]. Agricultural water-saving irrigation automation technology is a method of using modern information technology and automation technology to accurately irrigate farmland, which should first clarify its working principle, know its working characteristics, determine its future development trend, and then after a comprehensive analysis of the specific functions of this technology, this technology is comprehensively applied to the field of agriculture to achieve the purpose of improving the quality and efficiency of agricultural production, and promoting an overall increase in the utilization rate of water resources [3-6]. Agricultural water-saving irrigation automation technology is an advanced, precise and reliable irrigation method [7].

The agricultural water-saving irrigation system with water-saving irrigation automation technology as the core mainly includes sensors that can monitor the temperature and humidity of agricultural fields in real time, a transmission system that can transmit sensor data information, a central control room that can process data such as data cleaning, analysis and modeling, an intelligent processing center for irrigation time, irrigation mode and automatic determination of irrigation amount, an execution control system for irrigation operations, and a feedback module for real-time detection and feedback of irrigation schemes [8-10]. The effective combination of the above components forms a complete automated system for water-saving irrigation in agriculture, which allows for fine-tuned irrigation operations on farmland [11-12].

Agricultural automated irrigation system is characterized by strong adaptability, high demand, and convenient operation and maintenance, the core of which lies in the scientific and reasonable setting of the software control program after correctly connecting the piping equipment [13-14]. At present, the application of agricultural automated irrigation technology is constantly iterated, which greatly improves the efficiency of Chinese agricultural cultivation, but from the point of view of the degree of automation, there is still a certain degree of backwardness compared with the advanced foreign intelligent technology [15-16]. From the point of view of the current situation of the research, the mature PLC control, PID control, gateway communication, multifunctional sensing technology have been adopted and implemented to varying degrees, gradually presenting the characteristics of the whole set of constituent elements of the master control, acquisition, transmission, sensing, irrigation execution [17-18]. However, the overall irrigation system still exists the phenomenon of poor control effectiveness of the work process, and individual systems will appear without solution measures such as jamming, loss of control and other problems, most of which are caused by the layout of the irrigation situation with the field is not reasonable enough to match [19-21].

In this paper, the frequency conversion motor speed control technology is applied to the design of agricultural water-saving irrigation system, and the PID controller is used to control the motor for agricultural intelligent irrigation. DHT11 air temperature and humidity sensor and LM393 soil moisture sensor are combined to form the environmental information acquisition module of agricultural water-saving irrigation control system. The collected information is inputted into the PID controller, and the deviation generated by the control system is adjusted by analyzing the differential, integral, and proportional data and outputting the adjustment data, so as to accurately grasp and regulate the agricultural irrigation strategy, and to realize the optimal irrigation of crops on the basis of water saving and energy saving. After testing the automated irrigation control system, the research area for case study was selected and a control experiment was designed to explore the effectiveness of intelligent inverter water-saving irrigation technology by analyzing the amount of water used, input costs and crop yields under different irrigation technologies.

2. Intelligent frequency conversion irrigation automation control system

2.1 Constant-pressure water supply module based on frequency-controlled motor

2.1.1 Frequency conversion speed control constant pressure water supply technology characteristics

In recent years, motor speed control technology [22] has developed rapidly, and is widely used in various fields of industry, it not only has the characteristics of simple and convenient operation, but also has the advantage of very low probability of failure, and at the same time has the effect of saving energy, the speed control method of frequency conversion speed control is superior to other speed control methods such as voltage control speed control. Its main features are as follows.

(1) Frequency control motor is light in weight and small in size, and can be installed on the wall without occupying the space on the ground.

(2) Frequency control motor can be controlled manually and close remote control operation control, but also can be connected to programmable controllers and computers and other equipment to achieve automatic control of frequency control.

(3) Frequency conversion speed control has less impact on related power grid equipment, and its starting current is larger, about 1.7 times of the rated current of the motor.

(4) Frequency conversion speed control motor has various self-protection functions (such as short circuit, over-voltage, under-voltage, instantaneous power failure, etc.).

(5) Frequency conversion speed control can reduce vibration to reduce noise, and at the same time can extend the life of the equipment. Because frequency converter has the above characteristics, so many enterprises use the function of frequency converter to save energy, and it is widely used in various systems such as fan, water tired, metering and so on.

2.1.2 Constant pressure water supply module design

Constant pressure water supply is to be adjusted by the frequency converter speed, to maintain the agricultural irrigation network pressure for a constant value, and in the pipe network can withstand the pressure for the upper and lower limits of the value of the range, to ensure that the irrigation of the water supply pressure and irrigation water flow to achieve a balance and to ensure that the irrigation of water flow to meet the user's needs. This needs to be controlled by adjusting the speed of the motor, and the speed of each motor can be adjusted by the frequency converter through the contactor, relay group to adjust the irrigation system is used by a frequency converter to control a motor mode for irrigation. The pressure sensor is installed at the pump outlet to monitor the pressure of the network water, and the data will be transmitted to the industrial computer, the sensor detected data for real-time data, will change with the changes in the amount of water used in agricultural irrigation with the changes.

In this paper, in order to realize the constant pressure water supply utilizes PID control [23]. PID controller in the 1940s has been in the process control has a wide range of applications, PID controller as a kind of industrial control in the common industrial controllers, it is in accordance with the input and output deviation according to the proportionality, integral to control. The relationship between its input and output can be expressed as shown in the following equation:

$$u(t) = K_p \left[e(t) + \frac{1}{T_I} \int_0^t e(t)dt + T_D \frac{de(t)}{dt} \right] \quad (1)$$

Where $u(t)$ is the output of the PID regulator, $e(t)$ is the input of the PID regulator, Kp is the proportionality coefficient, T_I is the integral time constant. T_D is the differential time constant. Because it is very versatile, flexible conditions of use, there is a series of products, the use of only three parameters need to be set. Differential, integral and proportional control role is interrelated, not necessarily all used in practice, you can take one or two of these units, but the proportional link is indispensable.

In this case, the proportional link can proportionally reflect the deviation signal of the control system $e(t)$, and if there is a system deviation, the regulator then generates control proportional to it, thus reducing the deviation. Although proportional control is fast, in some systems there may be a steady state error. When the proportionality factor Kp is increased, the system will reduce the steady state error, but the stability may deteriorate. Eliminating the steady state error and improving the system's tolerance is the main function of integral control. Integral time constant T_I determines the strength of the integral effect, with the increasing of T_I, the integration speed will be slower and slower, and the integral effect will be weaker and weaker, and vice versa. And the integral link may also narrow the frequency band of the system. The role of the differential link can reflect the deviation of the signal change speed, with a certain degree of predictability, can foresee the deviation of the signal change trend, and can be in the deviation of the signal value becomes very large before the introduction of an effective early correction of the system signal, resulting in accelerating the response speed of the system to reduce the overshoot, reduce the regulation time. Because the differential reflects the rate of change, the output of the differential link is zero when the input does not change.

Meanwhile, the transfer function of the PID regulator can be expressed as the following equation:

$$\frac{U(s)}{E(s)} = K_p(1 + \frac{1}{T_i S} + T_d S) \tag{2}$$

As PID controller has the characteristics of simple structure, easy to realize and strong robustness, it is also an indispensable part of industrial control. At present, the application of PID in industrial control greatly improves the production efficiency and makes a certain contribution to the economic growth of the nation.

2.2 Environmental Information Acquisition Module

2.2.1 Air temperature and humidity sensors

The DHT11 [24] integrates the collection of temperature and humidity information into a single sensor and uses a single bus to control the output of direct digital signals, greatly reducing the complexity and size of the application circuit. At the same time, the WiFi module is utilized to achieve long-distance monitoring of temperature and humidity signals. The design has the advantages of low power consumption, low cost, and low data transmission rate. Together with the wireless transceiver chip, it makes the data acquisition node more mobile and flexible. So DHT11 is selected as the air temperature and humidity sensor of the system.

2.2.2 Soil moisture sensors

When the soil moisture sensor probe hanging, the triode base electrode is in the open state, the transistor triode output is 0. When inserted into the soil when the conduction current soil resistivity resistance value of the soil emitter content changes and changes. By detecting the soil water content can be realized on the soil moisture measurement and display, with high precision and reliability. The sensor can be used in a variety of crop growth environment conditions, such as greenhouses, lawns and other places for soil moisture monitoring. It is widely used in the measurement of soil temperature and humidity. However, the circuit structure is more complex, requiring special integrated circuits and peripheral devices to realize, and the cost is higher. The comparator uses a LM393 chip, which works smoothly and has a clear signal. So the LM393 soil moisture sensor is to be selected in the agricultural intelligent water-saving irrigation control system designed in this research [25].

2.2.3 Photoelectric sensors

Photoelectric sensor is one of the most widely used types of sensors, photoelectric sensor consists of three parts, which are light source, optical element and photoelectric element. The photoelectric sensor begins with the conversion of the measured non-electrical changes to the changes in the optical signal, and then proceeds to the operation of converting the optical signal to an electrical signal through the photoelectric element. Finally, the electrical signal is analyzed and processed by a signal processing circuit. Optoelectronic sensing technology is used to measure changes in physical quantities on the surface and inside the object. Parameters such as displacement, velocity, acceleration, temperature and pressure. It is now widely used in industrial and agricultural production and scientific research.

2.2.4 Carbon dioxide concentration sensors

The SGP30 gas sensor [26] can realize real-time monitoring of harmful environmental components without destroying the original structure and function of the monitored object, and has the advantages of high sensitivity and good selectivity. The SGP30 gas sensor is also used in industrial process control, and is so resistant to siloxanes that while other sensors typically run out of energy in less than a year, the SGP30 can be used for up to five years.

2.3 Overall design of intelligent water-saving irrigation system

Reasonable water-saving irrigation strategy is the basic guarantee for crop growth. This irrigation control system changes the previous method of irrigation water quantity basically relying on experience, through real-time online monitoring of soil temperature and humidity, etc., combined with the growth characteristics of different crops, to accurately grasp the irrigation time and irrigation quantity. The electrical control system based on intelligent frequency conversion regulation develops certain irrigation strategies through the setting of parameters such as period, duration, crop name, etc., with a view to achieving intelligent, water-saving and energy-saving irrigation under the premise of reasonable irrigation. The system divides the irrigation area based on parameters such as soil type, irrigation method and planted crops, selects representative crops for planting in different types of areas, and designs nodes with automatic collection and transmission functions for monitoring soil water content and other information. According to the data obtained from the real-time monitoring of the PC management and monitoring platform, the optimal irrigation time, irrigation volume, irrigation cycle and water-saving measures are formulated, and the growers are guided to irrigate reasonably, so as to realize the irrigation of different crops at the right time and the right amount, which not only achieves the purpose of water and energy conservation, but also realizes the optimal irrigation for the crops, and improves the yield and quality of the crops to a certain degree, and in the software monitoring part of the PC, the irrigation area is divided into different types of areas, and representative crops are selected for planting. In the upper computer software monitoring part of the design of the irrigation strategy query interface, the user can at any time through the interface to view the irrigation strategy, including the cycle, duration and other parameters.

The flow of constant pressure water supply irrigation strategy is shown in Figure 1. This irrigation strategy includes manual and automatic control methods. If the solenoid valve runs for more than 2 hours, the solenoid valve is forced to shut down to prevent the solenoid valve from running for a long time with the risk of burnout. Automatic irrigation first set the irrigation time and cycle, if the set cycle is not reached, then wait and continue to determine whether the irrigation cycle, if the irrigation cycle is reached to irrigate, from the time of irrigation to start timing until the end of the irrigation time.

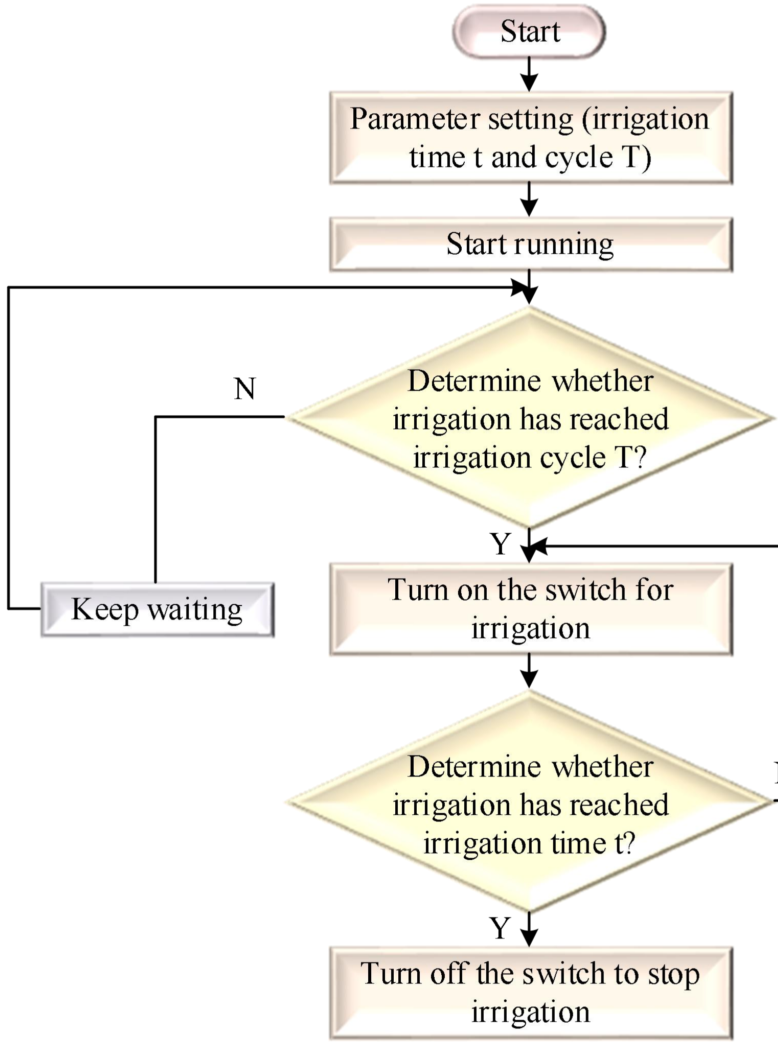


Figure 1 Flow chart of constant pressure water supply and irrigation

3. Intelligent irrigation system test and analysis

3.1 High-precision AD acquisition circuit test

In the agricultural water-saving irrigation system designed based on intelligent frequency conversion regulation, the voltage, water pressure and the rotation angle of the sprinkler are related to the safe and stable operation of the system. The rotation angle of the sprinkler can be set according to the actual situation in the intelligent control system. If the angle is not measured accurately, the sprinkler will run out of the limitation range, which will have an unsafe impact on the production area. Water pressure and voltage are both data that are prone to unsafe factors that need to be strictly monitored. In the actual design of the system circuit, because of the use of linear isolation photocoupler, the need for photocoupler resistance on both sides of the match and current limiting resistor size in the field environment to achieve the optimal effect, so the use of the parallel potentiometer method can be in the field of a variety of factors (temperature, mechanical structure) under the influence of the fine-tuning to adapt to the production of the actual value of the application. In the laboratory with an analog generator to measure the linearity of the designed circuit data shown in Figure 2, the sampling resistor using high-precision resistor 100 ohms, at this time to adjust the potentiometer to R45 = 72k, the size of the input current and voltage. Test results show that the system output voltage accuracy is high, the absolute value of the error is between 0-0.019V.

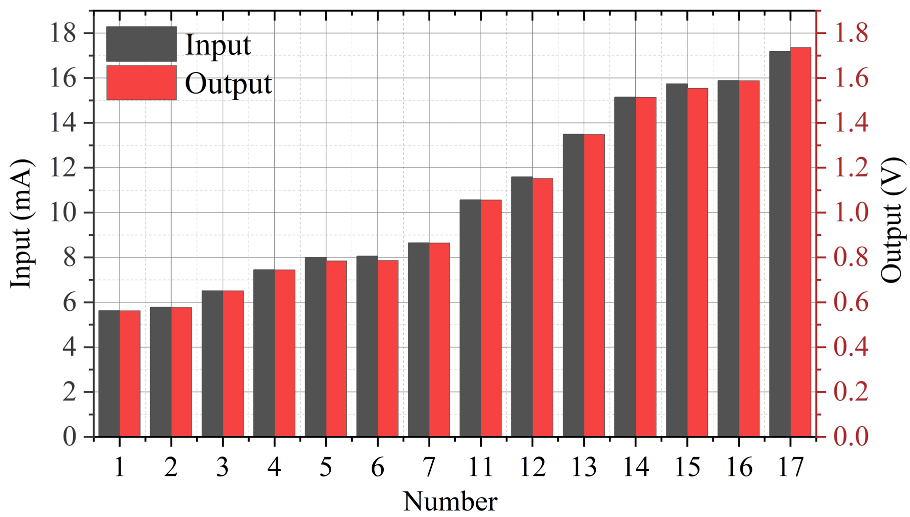


Figure 2 AD collection input quantity and output quantity

3.2 System sensing data upload test

The remote transmission function of the data sensor module is based on the installation of mobile SIM card GPRS module to realize, is the only channel for the host computer to receive on-site information for detection and control, it must be ensured that the stability of the GPRS module in line with the requirements of the work. Module can work properly before the need to set up a good communication address and IP number, so that the uploaded data packets and the background transceiver software to send instructions can be correctly received. Intelligent irrigation control system background transceiver software received packets as shown in Table 1. If the packet format or length of the packet sent is incorrect, it will show that the packet received is invalid, and there will be no packet loss after a long time of debugging.

Table 1 GPRS upload packet byte check

Function	Byte	Function	Byte
Irrigation machine address	2	Latitude value	48
Functional code	4	Timed start hour	1
Water pressure	2	Timed start minute	2
Voltage	4	Time stop hour	2
Soil temperature	14	Time stop minute	3
Soil moisture	14	Angular upper limit	3
Device status	3	Angle lower limit	1
Running time	4	Test state	1
Current angle	1	Pipeline flow	2
Running time	4	Type of irrigation machine	1
Current velocity	2	Lower time: hour	3
Signal state	2	Lower time: minute	4
Angle enable	4	Safe circuit condition	2
Cumulative check	2	Local/remote enable	2

4. Empirical analysis

4.1 Overview of the study area

4.1.1 Geographical overview

The study area of this study is Xinjiang Bosten Irrigation District, which is located in the north-central part of Bazhou, Xinjiang Uygur Autonomous Region, and is divided into Bosten Upstream Irrigation District and Bosten Downstream Irrigation District. The upstream irrigation area is called Yanqi Basin Irrigation Area, and the downstream irrigation area is called Peacock River Irrigation Area. The upstream of Bosten Irrigation District is in Yanqi Basin, and the ground range from Dashankou of Kaidu River to the first diversion hub of Kaidu River is hilly area, and the following area is plain area. Yanqi basin is a semi-enclosed mountainous basin, the basin topography is high in the north and low in the south, and the terrain is tilted from north-west to south-east, and Bosten Lake is the lowest point of the upstream irrigation area, and the lake surface elevation is about 1052m.

4.1.2 Climatic and hydrological characteristics

Due to the large Bosten irrigation area, the climate of the irrigation area varies by the influence of topography and geomorphology, when describing the meteorological elements of the irrigation area, the Yanqi meteorological station (86°61′E, 42°05′N) in Yanqi Basin and the Korla meteorological station (85°82′E, 41°73′N) in Kuyü area were used to represent the integrated description of the meteorological elements in the irrigation area respectively after the description of the meteorological elements of the irrigation area. The meteorological elements of Bosten irrigation area are shown in Table 2. Bosten Irrigation District is located in the middle of the Eurasian continent, the influence of oceanic climate is very weak, arid and little rain, evaporation is strong, belongs to the warm temperate continental desert climate. The multi-year average precipitation in the irrigation area is 65.2mm (Yanqi Meteorological Station) and 63.4mm (Korla Meteorological Station), which is concentrated in June to September. The average evaporation for many years is 1985mm and 2004mm, hot in summer, cold and less snow in winter, mainly sunny days throughout the year, long sunshine time, more solar radiation energy, big temperature difference between day and night, solar radiation energy in 145~158 and 147~153cal/ cm^2 . The gales in the area are mostly concentrated with late spring and early summer, with 4~6d of dry and hot winds every year. Spring and summer gales and wind sand, floating dust and dry hot winds are very serious hazards to agricultural production and people's lives.

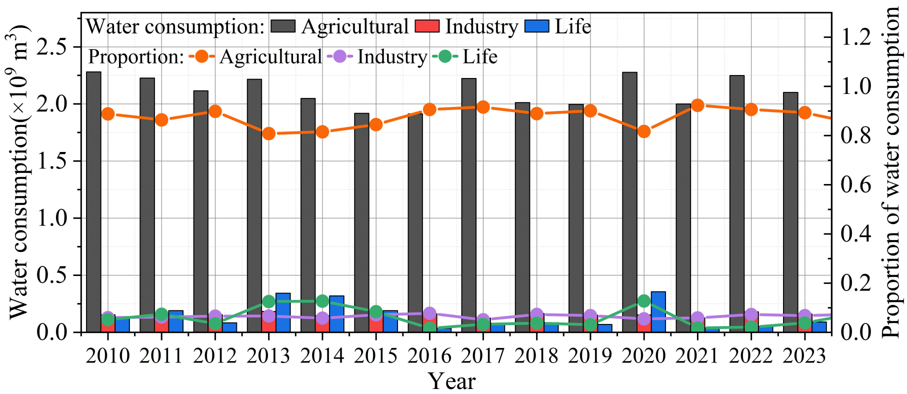
Table 2 An overview of meteorological elements in agricultural irrigation areas

Serial number	Index	Yanqi weather station	Korla weather station
1	Extreme maximum temperature (°C)	37.8	38.9
2	Extreme minimum temperature (°C)	-35.6	-27.4
3	Perennial average temperature	8.5	11.9
4	Final period (day/month)	8/4	15/4
5	First frost period (day/month)	25/10	18/10
6	Years of average frostless (days)	159	148
7	Annual average precipitation (mm)	65.2	63.4
8	Perennial average evaporation (mm)	1985	2004
9	Perennial average wind speed (m/s)	2.36	2.58
10	Year average maximum wind speed (m/s)	24.61	23.25
11	Prevailing wind	Northeast	Northeast
12	Wind sand weather (day)	23	25
13	Average annual relative humidity (%)	45.8	44.7
14	Maximum permafrost depth (cm)	102.6	64.9

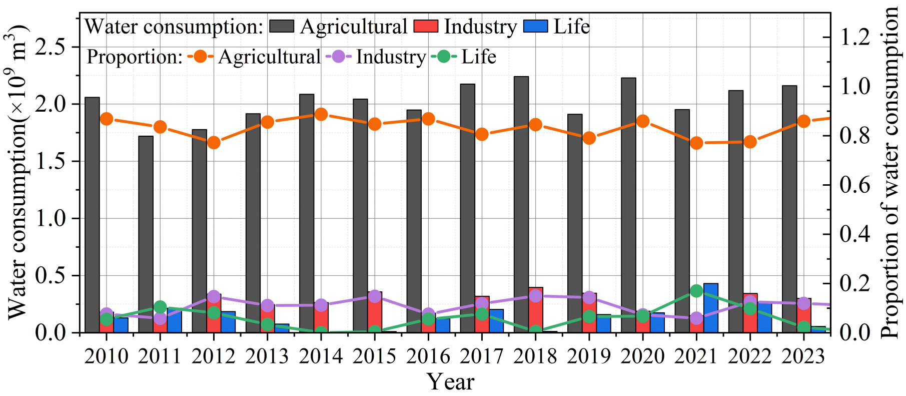
15	Average temperature in January (℃)	-12.4	-8.9
16	Average temperature in July (℃)	24.9	27.8
17	Perennial average sunshine hours (h)	3265.6	3021.4
18	Sun total radiation value (cal/cm^2)	145-158	147-153

4.1.3 Water use

The results of the analysis of water consumption of each industry in the study irrigation area are shown in Fig. 3, (a) and (b) are the results of the analysis of Yanqi Basin Irrigation Area and Peacock River Irrigation Area, respectively. It can be seen that agricultural water consumption in both upstream and downstream irrigation areas of Bosten is dominant. The share of agricultural water consumption in the upstream Yanqi Basin Irrigation District shows a fluctuating trend between 2010 and 2024, but the share of agricultural water consumption always stays above 80%, and the share of agricultural water consumption in the Yanqi Basin Irrigation District reaches the highest (92.33%) in 2021, and the agricultural water consumption in that year is $2.000\times 10^9 m^3$. The share of agricultural water consumption in the Peacock River Irrigation District also has no significant change, accounting for basically more than 77%, and agriculture in the downstream irrigation district occupies an important position. The proportion of industrial water use is much smaller than that of agricultural water use, indicating that the downstream industrial development has become smaller, and the local economic development is mainly improved by promoting agriculture. Therefore, the improvement of agricultural irrigation technology in the study area can significantly increase the utilization rate of water resources, create higher economic benefits, and protect the ecological environment.



(a) Yanqi basin irrigation district



(b) Kongqi river irrigation district

Figure 3 The amount of water used in the research area accounts for the result

4.2 Comparative analysis of water-saving irrigation inputs and outputs

The main crop grown in the research irrigation areas selected for this paper is cotton, and a controlled experiment was set up to analyze the application effect of the intelligent water-saving irrigation control system. Thirty hectares of farmland were randomly selected in each of the two study areas, which were equally divided into the traditional irrigation group, the low-flow irrigation group (drip irrigation) and the intelligent inverter irrigation group, and the experimental monitoring period was from April to November 2024, which is the growth cycle of the cotton crop. Agricultural irrigation inputs mainly refer to the inputs required for the application of the irrigation demonstration technology, including the annual running costs incurred during the operation of water-saving irrigation technology, the share of fixed investment in agricultural irrigation projects and other agricultural irrigation inputs. The annual running costs of water-saving agricultural irrigation technology include energy consumption costs, maintenance costs, personnel management costs and so on. Water-saving irrigation technology in the field is also a production factor for water users, and like other material inputs and labor, the adoption of water-saving technology inevitably requires input costs. Since the variable cost of input agricultural water conservation technology is a cost borne by farmers, it should be included in the short-term cost of farmers' product production to provide basic data for the analysis of the economic rationality of water conservation technology.

4.2.1 Analysis of water use for different irrigation technologies

The results of water consumption of different irrigation technology groups during the monitoring period are shown in Table 3, the average water consumption per hectare of intelligent frequency conversion irrigation technology is 3308.84 m^3 , which is much lower than that of the small flow irrigation technology group (4170.50 m^3/hm^2) and the traditional irrigation technology group (5851.13 m^3/hm^2). In addition, compared with the low-flow irrigation technology and traditional irrigation technology, the average water saving rate under the application of water-saving irrigation system based on intelligent frequency conversion regulation can reach 20.66% and 43.45%.

Table 3 Analysis of water use of different irrigation techniques

Group	Upstream irrigation area (m^3/hm^2)	Downstream irrigation area (m^3/hm^2)	Average (m^3/hm^2)
Water consumption			
Intelligent frequency conversion	3265.25	3352.42	3308.84
Small flow	4125.36	4215.63	4170.50
Tradition	5889.63	5812.63	5851.13
Intelligent conversion irrigation technique water-saving rate			
VS Small flow	20.85%	20.48%	20.66%
VS Tradition	44.56%	42.33%	43.45%

4.2.2 Analysis of operational inputs for water-saving irrigation technologies

(1) Intelligent frequency conversion water-saving irrigation technology operation inputs

The results of the operation inputs of the intelligent variable frequency water-saving irrigation technology proposed in this paper in Bosten upstream and downstream irrigation zones are shown in Table 4. The agricultural irrigation inputs of the intelligent inverter water-saving irrigation technology in the upstream and downstream irrigation zones are 1417.83 yuan/ hm^2 and 1435.26 yuan/ hm^2 respectively. The annual operating energy consumption was 385.42kW·h/ hm^2 and 387.52kW·h/ hm^2 , and the annual operating energy cost was 80.94 yuan/ hm^2 and

81.38 yuan/ hm^2 respectively. In addition, the operation of water-saving irrigation technology will generate maintenance and management fees, and the total operating costs of intelligent inverter water-saving irrigation technology in the upstream and downstream irrigation districts are 29,246.77 yuan/ hm^2 and 29,532.64 yuan/ hm^2 respectively.

Table 4 Intelligent water-saving irrigation technology input analysis

Accounting project	Categories	Metering unit	Quantity	
			Yanqi basin	Kongqi river
Irrigation zone	Quantity	m/ hm^2	9452.2	9568.4
	Price	yuan/m	0.15	0.15
	Cost	yuan/ hm^2	1417.83	1435.26
Energy consumption	Quantity	kW·h/ hm^2	385.42	387.52
	Price	yuan/ kW·h	0.21	0.21
	Cost	yuan/ hm^2	80.94	81.38
Maintenance fee	Cost	yuan/year	9652.00	9674.00
Management fee	Cost	yuan/year	15246.00	15542.00
Other variable input	Cost	yuan/year	2850.00	2800.00
Combined freight charges	Cost	yuan/ hm^2	29246.77	29532.64

(2) Operational inputs for low-flow agricultural irrigation technologies

The operational inputs of small flow agricultural irrigation technologies are shown in Table 5. The agricultural irrigation belt inputs for small and medium flow agricultural irrigation technologies in the upstream and downstream irrigation zones of the study area were 2028.69 yuan/ hm^2 and 2022.90 yuan/ hm^2 respectively. The annual operating energy costs of the low-flow irrigation technology in the two irrigation zones were 89.38 yuan/ hm^2 and 90.96 yuan/ hm^2, which were higher than those of the smart inverter water-saving irrigation technology. The combined operating costs for this irrigation technology were 312144.07 yuan/ hm^2 and 322480.86 yuan/ hm^2.

Table 5 Small flow irrigation technology runs the input accounting table

Accounting project	Categories	Metering unit	Quantity	
			Yanqi basin	Kongqi river
Irrigation zone	Quantity	m/ hm^2	13524.60	13352.68
	Price	yuan/m	0.15	0.15
	Cost	yuan/ hm^2	2028.69	2002.90
Energy consumption	Quantity	kW·h/ hm^2	425.63	433.15

	Price	yuan/ kW·h	0.21	0.21
	Cost	yuan/ hm^2	89.38	90.96
Maintenance fee	Cost	yuan/year	89526.00	88547.00
Management fee	Cost	yuan/year	215000.00	226340.00
Other variable input	Cost	yuan/year	5500.00	5500.00
Combined freight charges	Cost	yuan/ hm^2	312144.07	322480.86

(3) Conventional traditional agricultural irrigation technology operational inputs

The operational inputs of conventional and traditional agricultural irrigation technologies in the study area are shown in Table 6. Comparing with the above smart inverter irrigation technology and small flow irrigation technology, it can be found that the annual operating energy cost of conventional agricultural irrigation technology is the highest, which is 95.73 yuan/ hm^2 and 97.13 yuan/ hm^2. Maintenance costs (25634.5 yuan and 26654.3 yuan) and management costs (62,314 yuan and 63,354.5 yuan) are also much higher than those of the smart inverter irrigation technology. In terms of total operating cost it is lower than the low flow irrigation technology but much higher than the smart inverter irrigation technology proposed in this paper.

Table 6 Analysis of operation input accounting for conventional irrigation

Accounting project	Categories	Metering unit	Quantity	
			Yanqi basin	Kongqi river
Irrigation zone	Quantity	m/ hm^2	13052.48	13085.42
	Price	yuan/m	0.15	0.15
	Cost	yuan/ hm^2	1957.87	1962.81
Energy consumption	Quantity	kW·h/ hm^2	455.85	462.53
	Price	yuan/ kW·h	0.21	0.21
	Cost	yuan/ hm^2	95.73	97.13
Maintenance fee	Cost	yuan/year	25634.50	26654.30
Management fee	Cost	yuan/year	62314.00	63354.50
Other variable input	Cost	yuan/year	4200.00	4500.00
Combined freight charges	Cost	yuan/ hm^2	94202.10	96568.74

4.2.3 Results of crop output analysis

The results of comparative analysis of cotton crop output in the experimental farmland under different irrigation technologies are shown in Table 7. In the upstream irrigation study area, the average hectare yield of cotton crop under intelligent inverter water-saving irrigation technology was 5562.36 kg/ hm^2, the average hectare output value was 49,894.37 yuan/ hm^2 , and the net income per hectare was calculated to be able to reach 15,246.26 yuan/ hm^2 . In contrast, the average yield of cotton crop per hectare was 5263.42kg/ hm^2 and 5112.36kg/ hm^2 in the low-flow agricultural irrigation technology and traditional irrigation groups, respectively, and the selling price of the cotton crop in the experimental field was also lower, at 8.56 yuan/kg and 8.36 yuan/kg, respectively. The average net income per hectare (12,546.26 yuan/ hm^2 and 10,256.35 yuan/ hm^2) was much lower than that of the smart inverter irrigation technology and significantly different from that of the average net income per hectare in the group of the smart inverter irrigation technology ($P=0.021<0.05$). After the application of intelligent inverter water-saving irrigation technology in Bosten downstream irrigation district, the average hectare yield and crop price could reach 5629.35 kg/ hm^2 and 8.92 yuan/kg, and the average net income per hectare of the crop produced in the experimental field was 15826.36 yuan/ hm^2 , which was significantly different from that in the other two groups of irrigation technology.

Table 7 Analysis of cotton output under different irrigation techniques

Project	Average hectare yield (kg/ hm^2)	Price (yuan/kg)	Hectare average output (yuan/ hm^2)	Hectare average net income (yuan)	t	P
Upstream irrigation area						
Intelligent frequency conversion	5562.36	8.97	49894.37	15246.26	2.635	0.021
Small flow	5263.42	8.56	45054.88	12546.36		
Tradition	5112.36	8.36	42739.33	10256.35		
Downstream irrigation area						
Intelligent frequency conversion	5629.35	8.92	50213.80	15826.36	2.582	0.035
Small flow	5125.63	8.57	43926.65	11542.63		
Tradition	5006.95	8.32	41657.82	11023.36		

5. Conclusion

This paper is based on electrical control automation technology proposed intelligent frequency conversion agricultural water-saving irrigation control system, through the test experiments to check the operation of the system are normal. In

Xinjiang Bosten irrigation district to carry out empirical analysis test, the results are as follows:

(1) irrigation technology water saving rate analysis found that after the application of water saving irrigation system based on intelligent frequency conversion regulation, the average water saving rate of the test field reached 20.66% and 43.45% compared to the small flow irrigation technology and traditional irrigation technology respectively.

(2) In terms of technical operation input cost, the annual operation energy cost of intelligent inverter water-saving irrigation technology in Bosten upstream and downstream irrigation districts is 80.94 yuan/ hm^2 and 81.38 yuan/ hm^2, which is much lower than that of small flow irrigation technology and traditional irrigation technology.

(3) The analysis of crop output under different irrigation technologies found that the average yield per hectare in Bosten downstream irrigation area after the application of intelligent inverter water-saving irrigation technology reached 5629.35 kg/ hm^2, and the average net income per hectare of the output crop was 15826.36 yuan/ hm^2, which was significantly different from that of the other two groups of irrigation technologies ($P=0.035<0.05$).

In summary, the application of motor automation control technology to the field of agricultural irrigation can effectively improve the sloppy and empirical problems of traditional agricultural irrigation management, and then maximize the utilization rate of water resources, and truly realize the scientific and efficient agricultural irrigation operation effects.

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