

Implementation of Arc Current Control for Industrial Silicon Furnace Robot Based on OPC

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Abstract: The adaptability of the S7-200Smart PLC used in the burn-through system in harsh industrial environments and faster response time. However, PLC also encounter some challenges when writing complex control algorithms, especially in advanced application scenarios, which greatly restricts the wide application of PLCs. However, MATLAB performs well in computing efficiency, and is easy to apply a variety of advanced complex control algorithms, so the advantages of the two are combined by using OPC communication technology, that is, MATLAB communicates with PLC in real time, so that the RBF-PID algorithm can be run in MATLAB, and the parameters of the complex control algorithm are updated by using the real-time data detected by the PLC, so that the intelligent control algorithm can be realized in the PLC with good stability, This enables more precise ablation of the burn-through system.

Keywords: OPC;200smart PLC; MATLAB.

1. Hardware Applications for Ablation Control Systems

1.1. PLC applications

In the burn-through system, the PLC plays a central control role, so its selection is extremely critical in the hardware design part. The design uses the Siemens S7-200Smart PLC, a compact, modular programmable logic controller designed for small and medium-sized automation projects, with high cost performance and powerful functions. This PLC body comes with 14 points of input and 10 points of output, which

has the advantages of processing speed block, compact appearance, good durability and easy expansion. It has high-performance processing power and integrated Ethernet communication interface to facilitate data exchange with other devices and host computers. Digital/analog input and output modules, communication modules and signal boards are composed to support a variety of expansions to meet different application needs. The PLC control program is written through the STEP-7 software, which is highly compatible and powerful, and can greatly improve the development efficiency of the developer, as shown in Figure 1.

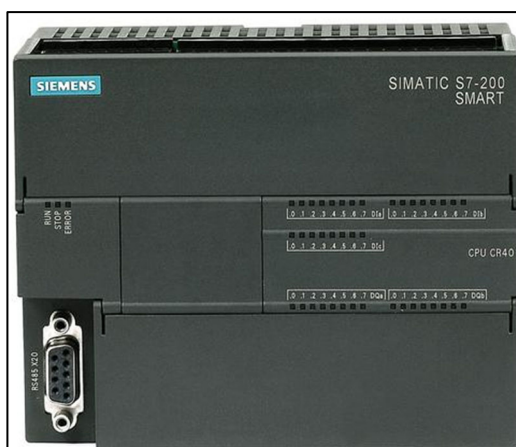


Figure 1. PLC physical drawing

1.2. Encoder applications

An encoder is a signal conversion device that converts a signal or data into a form of signal that can be used for communication, transmission, and storage. It can convert physical quantities such as angular displacement or linear displacement into electrical signals, among which the equipment used to convert angular displacement is called a code disc, and the device used to convert linear displacement is called a yardstick, and the commonly used encoders can be

divided into incremental encoders and absolute value encoders. In the ablation system, the encoder is mainly used to read the displacement speed of the electrode of the burn-through, and the encoder is installed on the rotating shaft of the hydraulic motor, and the speed of the motor is also the rotation speed of the encoder.

The use of encoder also needs to cooperate with the counter in the PLC, the counter of the PLC is divided into ordinary counter and high-speed counter, the signal of the ordinary

counter is limited by the scanning cycle of the PLC, if the frequency of the signal to be measured is higher than the current program scanning cycle of the PLC, the counting pulse will be lost. The high-speed counter is not affected by the PLC scanning cycle, the processing frequency is high, and

the 200smart supports 6 high-speed counters. In order to ensure the accuracy of measuring the speed of the hydraulic motor, a high-speed counter is used, and the speed calculation is performed every 0.5s.

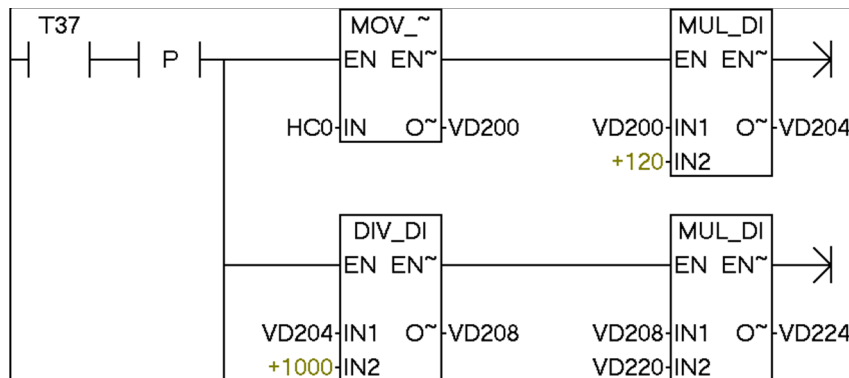


Figure 2. High-speed counter program

1.3. Sensor applications

The function of the water flow sensor is to detect the inlet and outlet water flow of the water-cooled cable, and the water-cooled cable is mainly used as a special cable in the transmission of high-current and high-power electrical equipment, especially in the application that requires efficient thermal management, and takes away the heat generated during the working process of the cable through the circulating flow of water, so as to effectively reduce the

temperature of the cable and improve the current-carrying capacity and operational stability of the cable. If the water flow rate is insufficient, it will lead to too high internal temperature of the cable, which will affect the performance and life of the cable, and may even lead to cable damage or safety accidents in serious cases. Commonly used flowmeters include turbine flowmeter, electromagnetic flowmeter, ultrasonic flowmeter, etc., and the system selects KEYENCE clamp-on ultrasonic flow sensor to output as an analog signal of 0-20mA.

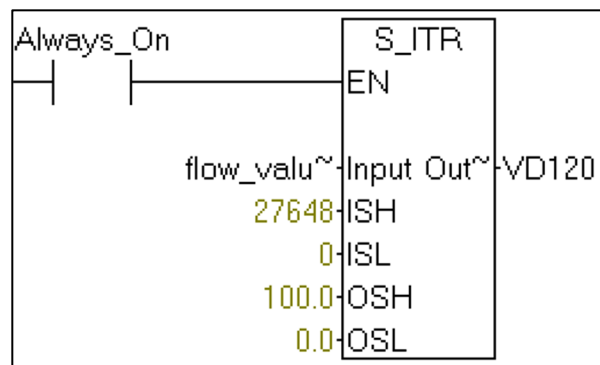


Figure 3. Water Flow Harvesting Program

A wire-actuated displacement sensor is a type of sensor used to measure linear displacement or position changes, which is widely used in various industrial and automation systems. When in use, the retractable wire rope of the sensor is connected to the tail of the electrode transmission mechanism, and when the electrode is displaced, the wire

rope will be extended or contracted accordingly to drive the measuring mechanism inside the sensor to carry out position measurement. The PLC reads the displacement data of the sensor through RS485 communication, and then obtains the real-time position of the electrode in the furnace eye through displacement conversion.

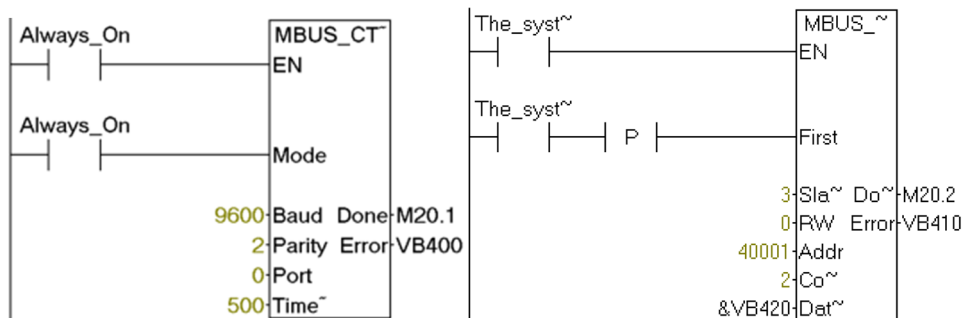


Figure 4. Displacement signal acquisition program

1.4. Rogowski coil applications

The principle of the current transformer is to convert the high current into a lower, easier to process signal, so that the measurement circuit can obtain the actual arc current value, and compare the value with the current value obtained by the arc model, the working characteristics of the arc of the burn-through device can be judged, and the error between the current value and the target current value can also be calculated as the input of the control algorithm. Conventional current transformers have an iron core, which is prone to

magnetic saturation, especially in the case of high currents, and the linearity may be affected, so it is not suitable for high-current devices such as burn-throughs. Rogowski coil is a non-contact current sensor, which has a fast response speed, small error, and a large rated current to be measured, which is suitable for the secondary side current measurement of electric arc furnace transformer. The integration circuit selects a dedicated Rogowski coil integrator, and the output is 4-20mA analog, which can be collected using the PLC analogue input module.

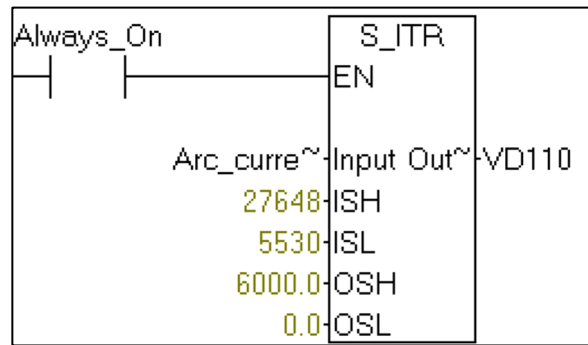


Figure 5. Current signal acquisition program

2. MATLAB Design for OPC Communication with PLC

The controller of the burn-through system is the S7-200Smart PLC, which shows higher reliability, stronger anti-interference, easy programming, ease of use, adaptability in harsh industrial environments and faster response time than the single-chip microcomputer that can also be used as the main controller. However, PLCs also encounter some challenges when writing complex control algorithms, especially in advanced application scenarios, which greatly restricts the wide application of PLCs. However, MATLAB performs well in computing efficiency, and is easy to apply a variety of advanced complex control algorithms, so the OPC communication technology is used to combine the advantages of the two, that is, MATLAB communicates with PLC in real time, so that the RBF-PID algorithm can be run in MATLAB, and the parameters of the complex control algorithm are updated by using the real-time data detected by the PLC, and

the update operation results are transmitted back to the controller PLC to adjust the action of the actuator, so that the stability is better. The implementation of intelligent control algorithms in the PLC enables more precise ablation of the burn-through system.

2.1. OPC communication principle

The real-time communication between MATLAB and PLC mainly relies on OPC (OLE for process control) technology, which is a software interface standard established based on COM/DCOM technology. The purpose of OPC is to establish a set of standards, which can be used for communication between the customer and the server, according to the OPC protocol, a standardized connection relationship can be established between the customer and the server, so as to realize the data service of the OPC server to the customer. In general, OPC servers are built on top of three main categories, including Server, Group, and Item, and the diagram visualizes the interrelationships between these three categories.

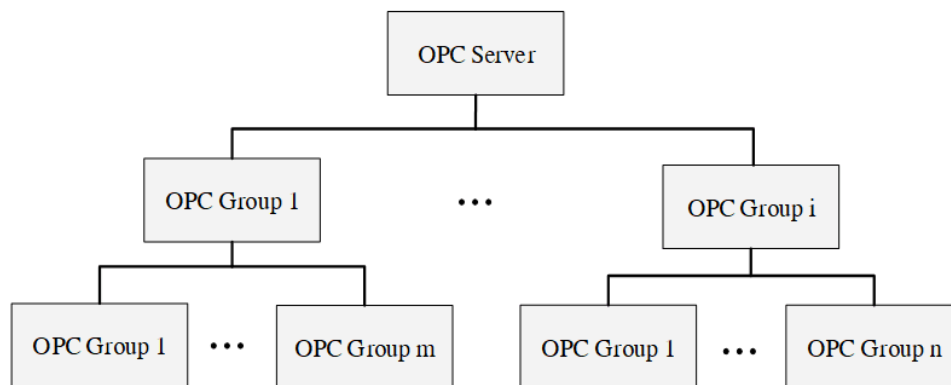


Figure 6. OPC Server Hierarchy Diagram

2.2. OPC communication design

KEPServerEX is an industry-leading industrial

communication and data connectivity platform developed by PTC. It supports hundreds of industrial protocols, including

common PLC protocols such as Modbus, OPC UA, Profibus, BACnet, DeviceNet, etc., this paper uses KEPServerEX software to establish an OPC server, exchange data with 200smart PLC, and use the OPC toolbox in MATLAB software as the OPC client. The design of the control program mainly includes the MATLAB control algorithm, the processing program of each sensor signal in the PLC, and the control program to control the displacement of the electrode of the burn-through.

The RBF-PID control algorithm is written and implemented in Matlab and its Simulink, the optimized PID control parameters are calculated, and the set values are sent

to the variable manager of KEPServerEX through the OPC communication protocol. Through communication with PLC, the setting result in the variable manager is sent to the control unit PLC, the PID control parameters after tuning optimization are imported into the PID control program section of PLC, and finally the electrode displacement is controlled by the PLC output analog signal to control the opening of the electro-hydraulic servo valve. The PLC control unit uploads the collected sensor monitoring data as feedback values to KEPServerEX and exchanges data with Matlab. The communication process is shown in Figure 7.

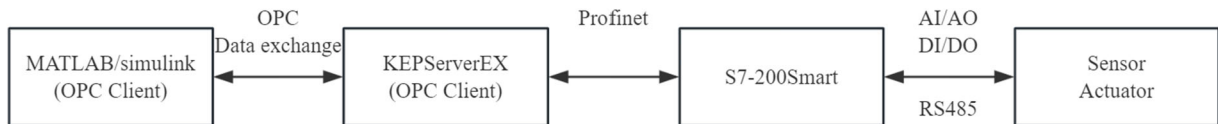


Figure 7. Schematic diagram of the communication process of the control system

The following takes Siemens S7-200Smart PLC as an example to build a server, Siemens S7-200Smart PLC supports TCP/IP communication protocol, this time the actual PLC is used for data transmission, mainly describing the key operations and key settings in the process of building an OPC server.

Firstly, the connection configuration of PLC and programming software STEP-7 is carried out, the PLC and

the test PC are connected with network cables through the network port, the corresponding items of the STEP-7 software are opened, the corresponding equipment is selected, the IP address and other settings of the equipment are configured, and the corresponding PLC is found and connected by searching for the equipment with the same display address, as shown in Figure 8.

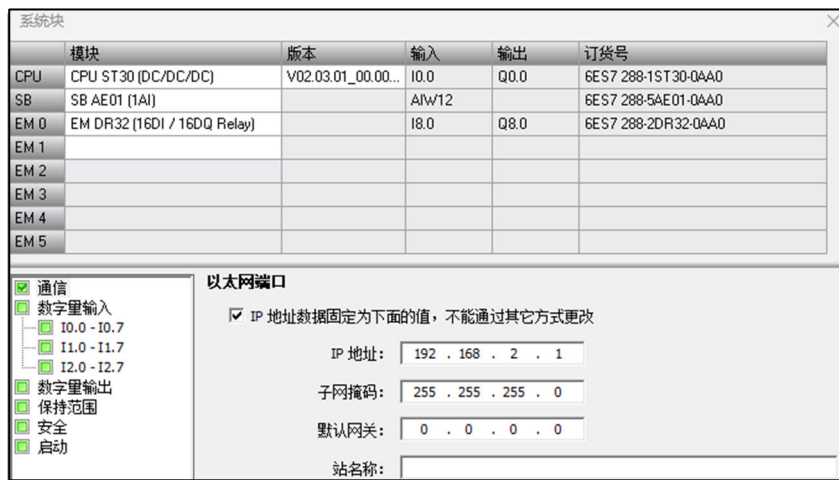


Figure 8. PLC Configuration Interface

After completing the configuration configuration related to step-7, use the OPC server industrial software KEPServerEX to select the channel protocol corresponding to the S7-

200Smart PLC, and select Siemens TCP/IP Ethernet in the drop-down list, as shown in Figure 9.

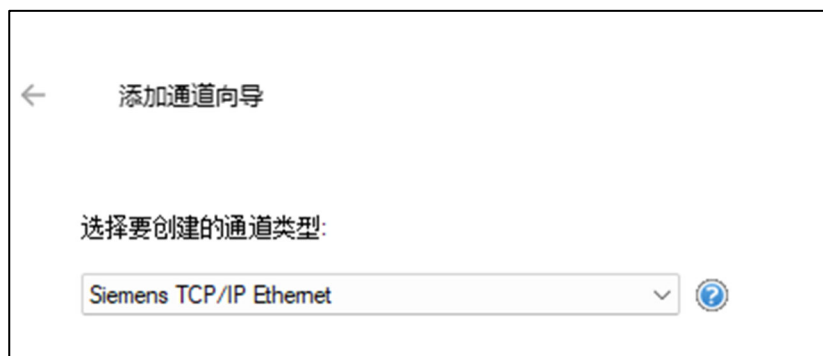


Figure 9. Channel type setting interface

In addition, it is also necessary to set the network adapter for connection, and here the network adapter of the machine is selected, and the default value in the option represents the

automatic selection of the network adapter of the machine, as shown in Figure 10.

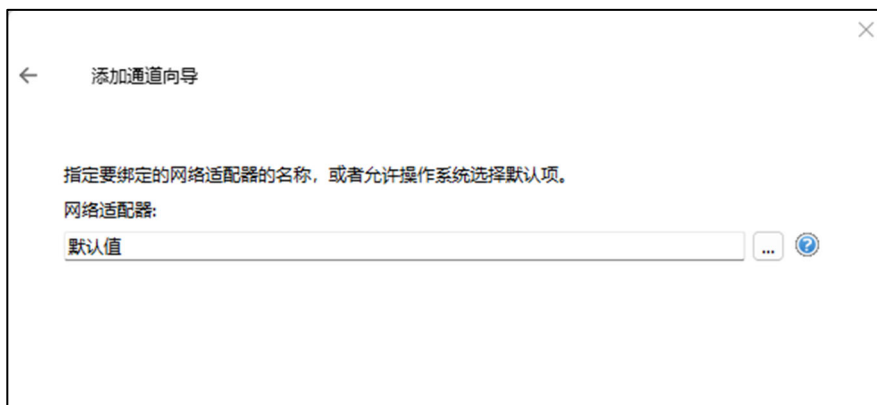


Figure 10. Network adapter setup screen

Next, add the corresponding specific device and select the model of the actual connected device, as shown in Figure 11,

here select S7-200Smart.

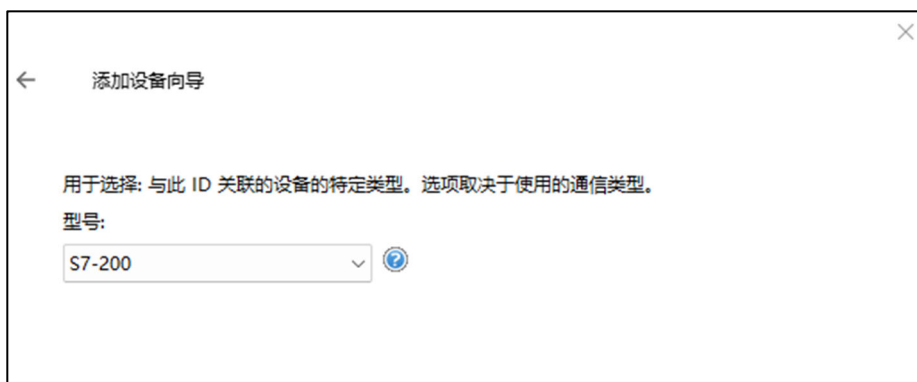


Figure 11. Device model configuration page

Finally, the ID of the connected device is set, as shown in Figure 12, and the ID here is the device ID that is set in the

Botu, that is, the communication address of the actual PLC.



Figure 12. Mailing address setting screen

After the connected device is added, you need to set the tags in the device, create tags such as the target current value, the current current value, and the electrode displacement velocity, as the data transmitted when interacting with MATLAB, and the tags are connected to each other with the relevant quantities in the device, and these tags will be

displayed in the address space in the OPC server, and the attributes of the tags include the tag name, communication address, data type received and sent, client access mode, scanning rate, etc., and these attributes are set in turn, as shown in Figure 13.



Figure 13. Variable attribute configuration page

After the OPC server is assembled, use the variable monitoring table in STEP-7 and the OPC Quick Client of KEPServerEX to test and verify whether the server is

successfully assembled. As shown in Figure 14, the data in the Botto was successfully transferred to the OPC server, and the test verification was successful.



Figure 14. Test the server setup interface

In summary, the industrial software KEPServerEX has completed the data acquisition of multiple address variables in the Siemens S7-1200 PLC, so the establishment of the OPC server is basically completed.

Then create an OPC client, add an OPC server in the OPC toolbox in Matlab, configure the client's communication parameters, access the KEPServerEX variable manager, and add the variables that need to be transferred, as shown in Figure 15.

Then create an OPC client, add an OPC server in the OPC

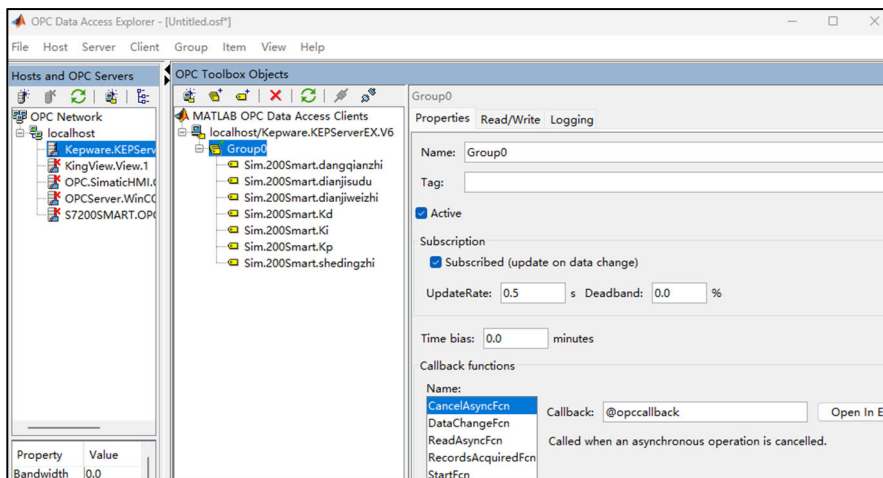


Figure 15. Matlab's OPC client configuration parameter interface

Finally, the relevant properties for the OPC Configuration, OPC Read, and OPC Write modules were set in the Simulink

simulation environment and connected to the variables in the KEPServerEX Variable Manager, as shown in Figure 16.

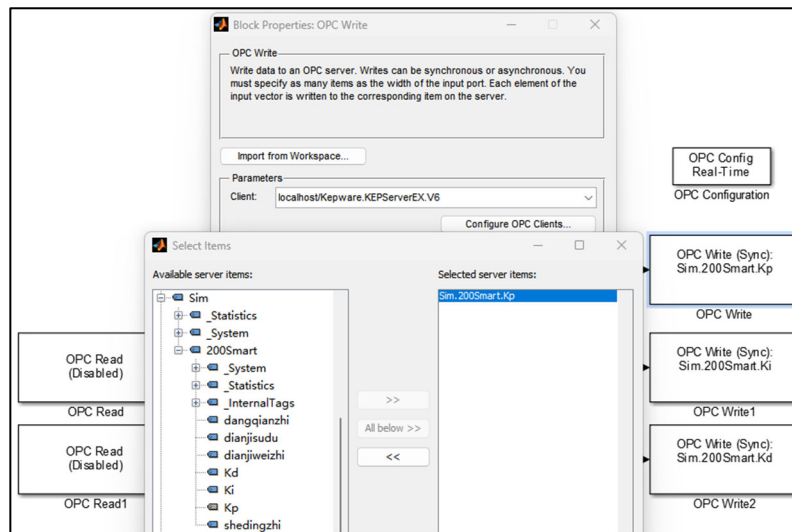


Figure 16. OPC Client variable connection configuration

3. Summary

Using the OPC protocol, the data of the PLC was successfully acquired and exchanged with MATLAB. The data of various sensors are uploaded to MATLAB through the OPC server, and the arc current of the burn-through device is controlled by using the powerful computing power of MATLAB/simulink.

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