Control System Design for SOLYS Gear Drive Solar Tracker (Postprint)

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Abstract

The advancement of solar tracking research has imposed heightened requirements for the intelligence of solar tracker control systems. This work innovatively proposes, using the SOLYS Gear Drive solar tracker as the instrument platform, to establish communication between the control host and the solar tracker within a local area network (LAN), as well as between the LAN and the Internet, via routers. With LabVIEW, a virtual instrument development software, as the software platform, and through integrated invocation of the Baidu Maps Application Programming Interface (API) and command script files, a control system is designed. The system enables instrument status monitoring, command control, remote access, and other functionalities. It is characterized by rich functionality, simple operation, excellent interface visualization, and strong universal applicability.

Full Text

SOLYS Gear Drive Sun Tracker Control System Design

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Abstract

The advancement of sun tracking research has increasingly demanded greater intelligence in sun tracker control systems. Using the SOLYS Gear Drive sun tracker as the hardware platform, this paper innovatively proposes a method that establishes communication between the control host and sun tracker within

a local area network (LAN), as well as between the LAN and the Internet via a router. Leveraging the virtual instrument development software LabVIEW as the software platform and comprehensively utilizing the Baidu Maps JavaScript API and command script files, we have designed a comprehensive control system that enables real-time status monitoring, command control, and remote access of the instrument. The system offers rich functionality, simple operation, excellent interface visualization, and broad applicability.

Keywords: sun tracker; control; LAN; mode; Baidu Maps; script file

Since the 1990s, progress in meteorological observations and solar energy utilization has placed higher demands on sun tracking technology. Various types of sun trackers have been developed domestically and internationally, evolving from single-axis to dual-axis tracking and from single-mode to hybrid tracking approaches [1]. Sun trackers have continuously advanced toward the goals of high precision, full automation, and multi-functionality. Currently, we have entered the era of automation chips, where sensors and processors work in combination to achieve automatic sun tracking, making the control system the core of operation [2]. However, most sun trackers are not equipped with dedicated control systems, or their control functions are relatively limited, operations lack intelligence, and interface visualization is poor. Therefore, developing a sun tracker control system with rich functionality, convenient operation, clear interface, and strong universality has become an urgent necessity.

1. Instrument Description

The SOLYS Gear Drive sun tracker, manufactured by Kipp & Zonen of the Netherlands, is a new type of fully automatic dual-axis sun tracker. It features a built-in GPS receiver to obtain time and geographic location information, which is processed using the J.J. Michalsky algorithm (1988) to calculate solar position information. Fine-tuning of the pointing position is achieved through calibration by a four-quadrant sensor, achieving a precision of 0.02°. The SOLYS Gear Drive employs a gear transmission system with a maximum load capacity of 80 kg and maximum torque of 60 Nm, capable of withstanding strong winds up to 20 m/s. It supports both 220V AC and 24V DC power supplies and includes a built-in heater, extending its operating temperature range to -50°C to 60°C, enabling operation in harsh environments.

2. System Design

2.1 System Principle Currently, most sun trackers utilize TCP ports 15000 and 15001 for instrument monitoring. The TCP 15001 port does not support sending host commands or requests; it only supports one-way information transmission from the instrument to the host, including current time information, latitude and longitude data, solar position information, and motor action details, with an update rate of 1 second. In contrast, the TCP 15000 port supports both host command transmission and timely feedback reception. The usage instructions for some primary commands are shown in Table 1 .

The SOLYS Gear Drive sun tracker operates in two main modes: tracking mode and standard mode. In tracking mode, the instrument automatically tracks the sun, while in standard mode, it moves according to action commands to complete a predetermined motion trajectory. Mode switching is achieved through the FU command.

Table 1 Control Command Table

Command	Function	Command	Function
MO*	Set motor acceleration	CL*	Stop motion
MS*	Get motor status	CO*	Restore factory settings and restart
PA*	Pause for a period	PO*	Point to a specific position
RE*	Get solar position	FU*	Set operating mode
HO*	Return motor to initial position	SP*	Set solar running speed
TI*	Get universal time	LL*	Set position and pressure
VM*	Set motor speed	MC*	Set motor operating current
WA*	Restart according to current settings		

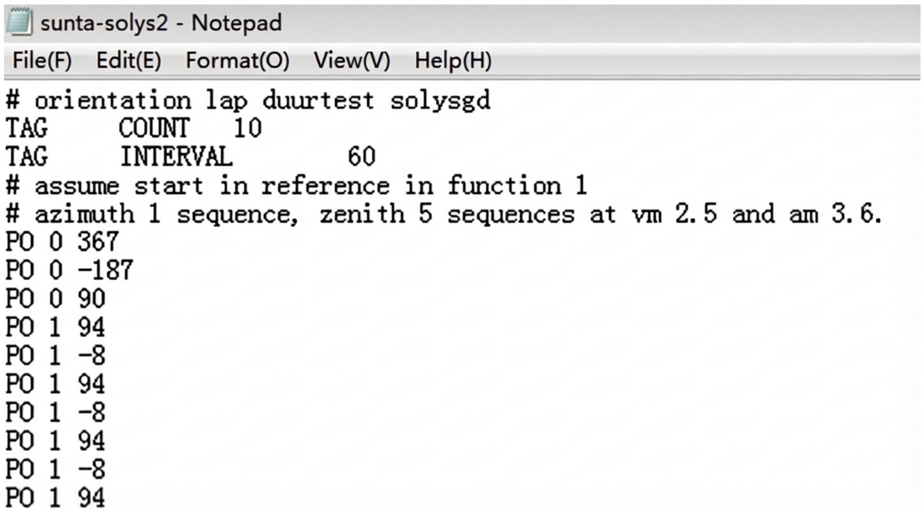
Note: Commands marked with can only be used in standard mode.*

2.2 System Architecture The system architecture is illustrated in Figure 4

. While RS232 serial communication can achieve full-duplex operation, it suffers from low data transmission rates, limited distance, and poor security [3]. The SOLYS Gear Drive sun tracker not only supports RS485 serial communication with the host but also features an Ethernet RJ45 interface. Therefore, the host can be directly connected to the instrument or both can be connected to a LAN simultaneously, enabling status monitoring and command control of the instrument. If further connected to the Internet, remote access to the instrument can be achieved. This approach offers high transmission rates, unlimited distance, and good security since the host accesses the instrument via IP address.

As shown in Figure 1

, a LAN is established using a router, with the host and instrument connected to different LAN ports and the WAN port connected to the Internet. The host



sunta-solys2 - Notepad
File(F) Edit(E) Format(O) View(V) Help(H)

```
# orientation lap duurtest solysgd
TAG     COUNT   10
TAG     INTERVAL        60
# assume start in reference in function 1
# azimuth 1 sequence, zenith 5 sequences at vm 2.5 and am 3.6.
PO 0 367
PO 0 -187
PO 0 90
PO 1 94
PO 1 -8
PO 1 94
PO 1 -8
PO 1 94
PO 1 -8
PO 1 94
```

Figure 1: Figure 4

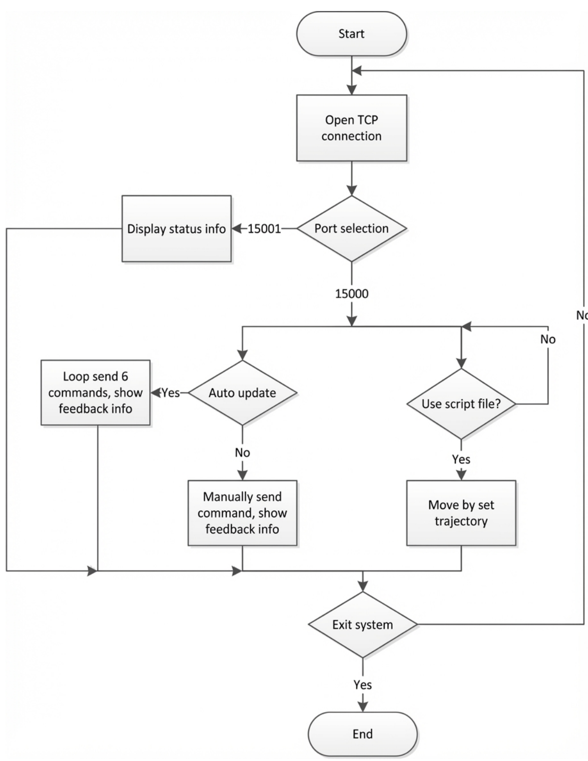


Figure 2: Figure 1

then properly configures the router' s DHCP server to assign an IP address to both the host and the instrument [4].

Using the TCP protocol in LabVIEW data communication, LAN communication between the sun tracker and host can be implemented. The TCP connection opening function is shown in Figure 2

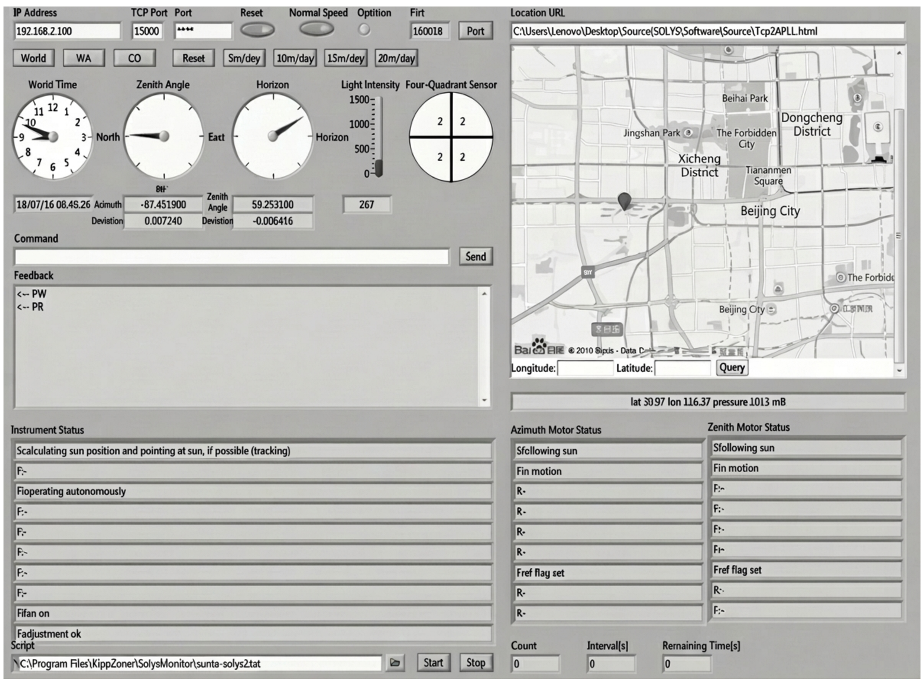


Figure 3: Figure 2

. In addition to entering the IP address, the remote port or service name must be specified to establish the TCP network connection. The remote ports for the SOLYS Gear Drive sun tracker are shown in Figure 3

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**Figure 1

System Schematic Diagram**

**Figure 2

TCP Connection Opening Function**

**Figure 3

Remote Port Numbers**

**Figure 4

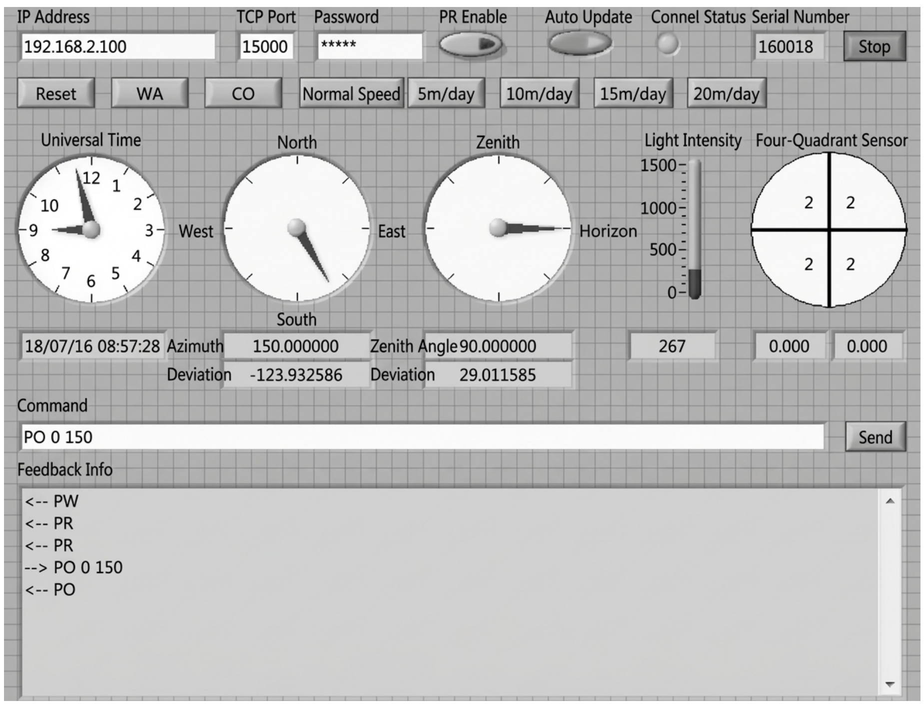


Figure 4: Figure 3

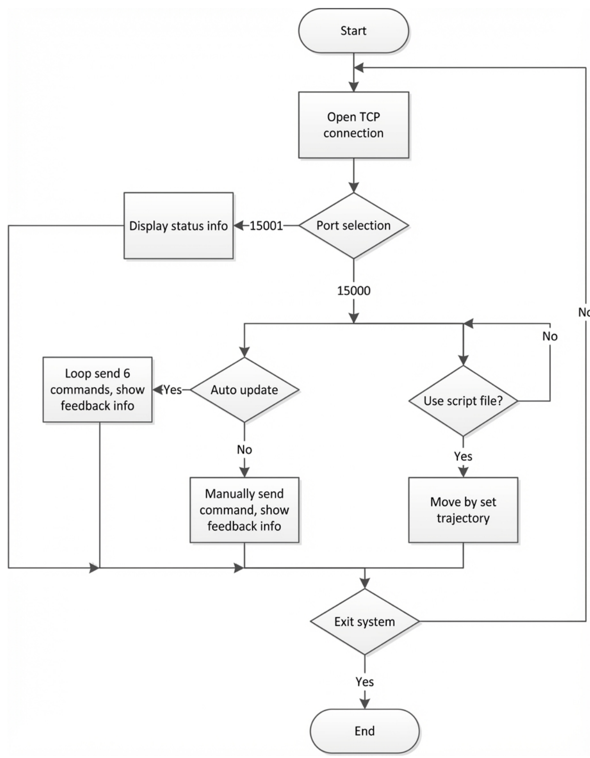


Figure 5: Figure 1

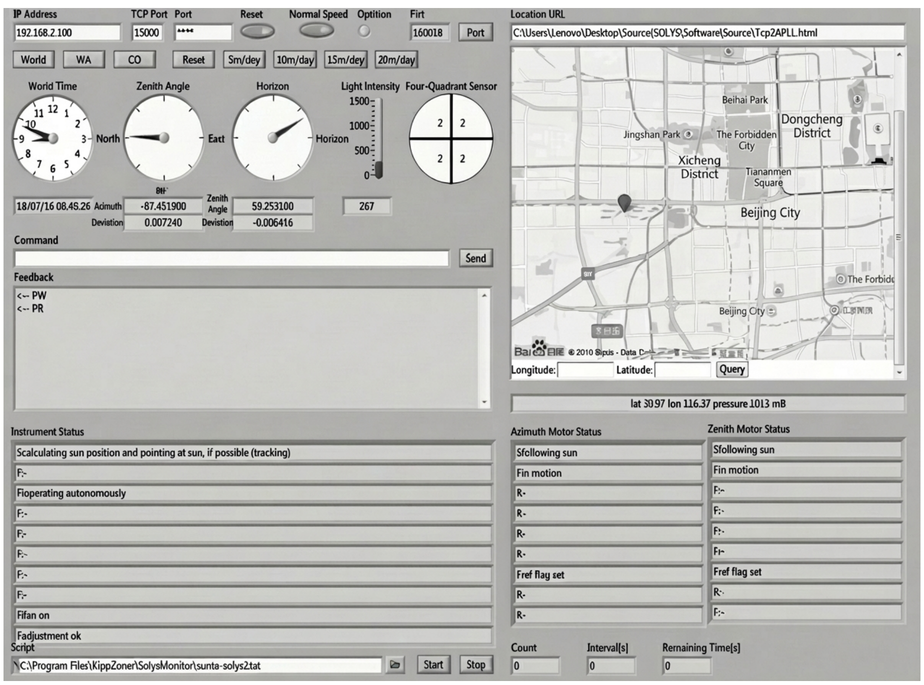


Figure 6: Figure 2

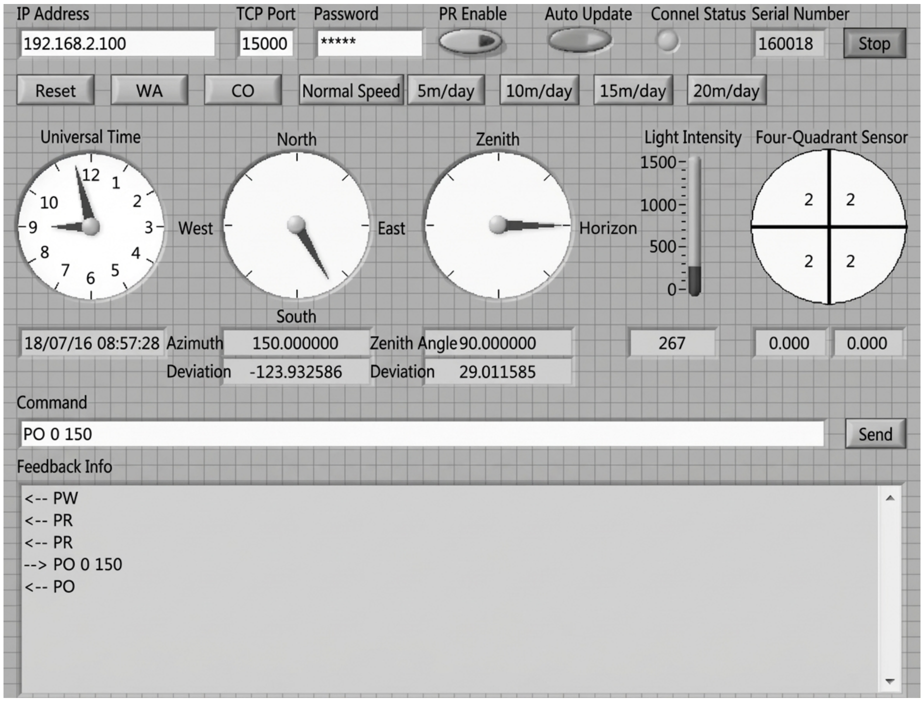
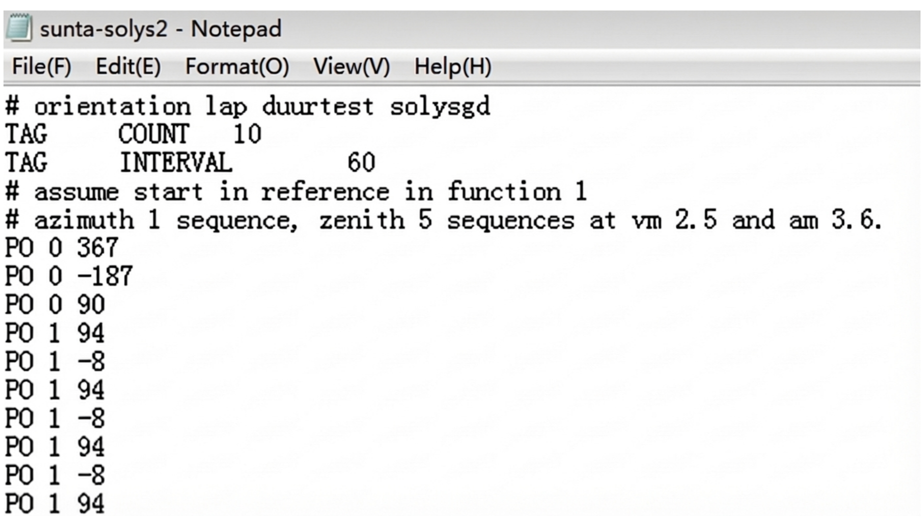


Figure 7: Figure 3




```
# orientation lap duurtest solysgd
TAG     COUNT   10
TAG     INTERVAL        60
# assume start in reference in function 1
# azimuth 1 sequence, zenith 5 sequences at vm 2.5 and am 3.6.
PO 0 367
PO 0 -187
PO 0 90
PO 1 94
PO 1 -8
PO 1 94
PO 1 -8
PO 1 94
PO 1 -8
PO 1 94
```

Figure 8: Figure 4

Control System Architecture Diagram**

System functionality can be implemented through port selection. If TCP port 15000 is selected, commands can be sent to the instrument from three sources: automatic updates, manual transmission, or script files. If automatic update is enabled, the host cyclically sends six commands– "CT, LL, IS, MS, SI, SE" –to the instrument and displays the feedback information in real-time on the LabVIEW front panel. If manual transmission is selected, commands can be entered in the command input box, which must comply with the instrument' s operating mode and meet specific format requirements. If commands are stored in a script file (e.g., a txt file), the system can read and execute them sequentially, enabling planned motion trajectories for the instrument.

2.3 Front Panel Design The LabVIEW-based front panel interface design is shown in Figure 5

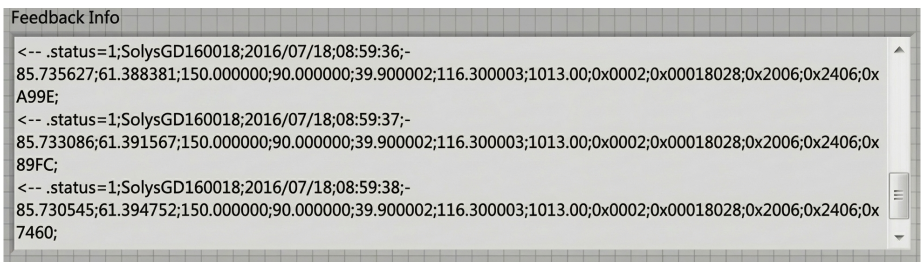


Figure 9: Figure 5

, with TCP port 15000 selected to enable host command transmission to the instrument.

**Figure 5

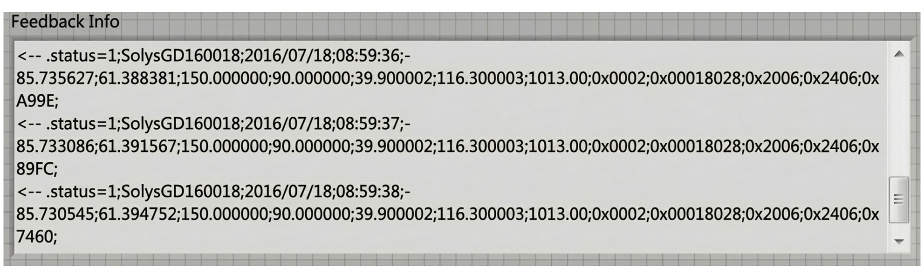


Figure 10: Figure 5

Front Panel Interface**

The interface is divided into the following functional modules:

1. **Communication Settings:** Input the instrument' s IP address and TCP port to establish communication between the host and instrument, with connection status displayed.
2. **Password Protection:** Password protection (PRotection) is configured for the "Send Command" function. On the front panel, PR enable can be activated or deactivated. If disabled, command usage permissions are unrestricted. If enabled, commands are only transmitted when the correct password is entered, further enhancing control system security.
3. **Auto-Update:** When auto-update is enabled, the host cyclically sends six commands—"CT, LL, IS, MS, SI, SE"—to obtain information including "current universal time and pointing position, longitude, latitude, and pressure, instrument status, motor status (including azimuth and zenith motors), solar intensity, and instrument serial number," which is displayed using front panel controls.
4. **Status Display:** The azimuth and zenith angle display controls show the pointing position and calculate and display the error between the pointing position and current solar position in real-time. The light intensity value and four-quadrant sensor value controls display solar intensity values and the voltage values obtained through photoelectric conversion by the four-quadrant sensor (with one significant digit). The conversion relationship depends on sensor parameters. Using JavaScript to call the Baidu Maps API, an "input latitude and longitude to display location" application is developed [5], and its storage path is sent to the browser control in LabVIEW as a URL [6], enabling real-time display of latitude and longitude information on Baidu Maps. By default, the latitude and longitude come from the instrument' s GPS data, but manual input for location queries is also supported. The instrument status display control shows the current operating mode, operation status, automatic or manual operation, internal heating, and adjustment conditions. The motor status display control shows motor motion status and operating current.
5. **Common Commands:** Frequently used commands are represented as controls, including reset, WA, CO, and solar running speed settings. The solar running speed refers to the speed in the sun tracking algorithm; for example, selecting "5min/day" means completing the sun's daily trajectory within 5 minutes, with the instrument' s pointing following this motion.
6. **Command Input:** Commands can be manually entered in the input box. For example, entering "PO 0 150" commands the azimuth motor to point to 150 degrees, where 0 is the azimuth motor ID. After execution, feedback information and azimuth angle are displayed promptly. A partial front panel view is shown in Figure 6 [FIGURE:6].
7. **Script Files:** Commands stored in script files (e.g., txt files) are read and sent to the instrument for execution, enabling motion along planned paths. A script file and its execution status are shown in Figure 7 [FIGURE:7]. This script file contains 10 commands with a 60-second transmission interval, setting maximum motor speed to 2.5°/s and maximum acceleration to $3.6°/s^2$.

Figure 6 [FIGURE:6] Partial Front Panel under PO Command

Figure 7 [FIGURE:7] A TXT Script File and Its Execution Status

If TCP port 15001 is selected, the instrument sends status information to the host for display in real-time, as shown in Figure 8 [FIGURE:8]. The format is: "information type; host name; date; time; solar azimuth; solar zenith; azimuth motor position; zenith motor position; latitude; longitude; pressure; status code; operating status; azimuth motor status, zenith motor status; checksum," where operating status and motor status are represented in encoded form.

Figure 8 [FIGURE:8] Instrument Status Information

2.4 Remote Access Using the control host as a remote access server and leveraging LabVIEW' s built-in Web publishing tool, the control system' s front panel can be published to the Internet. The Web publishing tool settings are shown in Figure 9 [FIGURE:9].

Figure 9 [FIGURE:9] LabVIEW Web Publishing Tool

Since the control host and instrument communicate through a router-configured LAN, remote access clients within the same LAN can directly access the front panel using the published URL. If clients access the server through the public network, proper port mapping must be configured on the router [7]. The remote access panel for the control system is shown in Figure 10 [FIGURE:10].

Figure 10 [FIGURE:10] Control System Remote Access Panel

Conclusion

The SOLYS Gear Drive sun tracker control system utilizes an Ethernet interface to achieve communication between the host and instrument within a LAN and between the LAN and the Internet. IP addressing enables host access to the instrument, overcoming the limitations of traditional serial communication—slow speed, short distance, and poor security. The LabVIEW-based control panel design offers rich functionality, simple operation, and excellent interface visualization. Using the Web publishing tool to publish the front panel to the Internet enables remote instrument access, greatly satisfying user operational requirements. Furthermore, with simple command modifications, this system can be applied to other sun trackers, demonstrating strong universality.

References

[1] Zhigang Zhu, Wei Chen, Xingkui Mao. Overview of Automatic Sun Trackers [C]. Proceedings of the 18th National Power Supply Technology Annual Conference, 2010: 479-481.
[2] Jianhua Zhao, Tingting Zhang. Research and Design of Sun Tracking Control System [J]. Electronic Measurement Technology, 2016, 39(3).
[3] Ping Xiang, Yuqing Bi, Jianmin Cheng, Fang Chen. Design of Sun Tracking

Control System Based on ARM [J]. Computer Measurement & Control, 2009, 17(6): 1102-1105.
[4] Yong Zhang, Deyun Zhang, Xuxian Jiang, Wei Huo. Router Security Configuration Management [J]. Computer Engineering, 2000, 26(8).
[5] Flanagan. JavaScript: The Definitive Guide [M]. Beijing: Mechanical Industry Press, 2007.
[6] Leping Yang. LabVIEW Advanced Programming [M]. Beijing: Tsinghua University Press, 2003.
[7] Feng Fu, Hongzhang Xu. Analysis and Application of Port Mapping [J]. Tianzhong Journal, 2006, 21(2): 59-60.

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