Postprint: Sunroof Actuation and Status Detection Using Two Conductive Slip Rings

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Abstract

Currently, rotatable astronomical domes remain in extensive use. During operation, the dome can rotate 360°, with the telescope conducting observations through an opened skylight. The skylight at the Xinglong Observatory Base of the National Astronomical Observatories utilizes five slip rings, yet cannot detect its status. To simplify the skylight' s status detection and drive system while enhancing its reliability, a novel skylight status detection and drive circuit has been designed leveraging the unidirectional conduction characteristic of diodes. This circuit requires only two slip rings and two limit switches to achieve skylight status detection and drive control. When the skylight is in a limit position, the limit circuit composed of diodes permits only unidirectional current flow. When the skylight is in an intermediate position, it allows bidirectional conduction. The circuit has been successfully applied to skylight status detection and control in multiple domes, including the 85 cm telescope. The skylight status detection and control circuit significantly simplifies the measurement and control system and enables fault detection.

Full Text

Abstract

Rotating astronomical domes with slits remain widely used in observational astronomy. These domes can rotate 360 degrees, allowing telescopes to observe through the opened slit. At the Xinglong Observatory of the National Astronomical Observatories, some telescopes employ five conductive slip rings to control the dome slit, but this configuration cannot detect the slit status. To simplify the state detection and drive system while improving reliability, a novel dome slit state detection and drive circuit has been designed based on the unidirectional conduction characteristic of diodes. This circuit requires only two conductive slip rings and two limit switches to achieve both state detection and drive control for the dome slit. When the slit reaches a limit position, the limit circuit composed of diodes permits current flow in only one direction; when the slit is in an intermediate position, current can flow bidirectionally. The circuit has been successfully implemented in multiple dome slits, including the 85 cm reflecting telescope at Xinglong Observatory. Practical application demonstrates that this state detection and control circuit significantly simplifies the measurement and control system while enabling fault detection.

Keywords: Slit state detection; Conductive slip ring; Thyristor; Field effect transistor; Bridge switch

Introduction

The dome is a mechanical device that protects astronomical telescopes and coordinates their operation. During operation, the dome can rotate while the telescope observes through the opened slit on the dome [1]. Currently, traditional domes still see extensive use, with most employing three-phase AC power for slit drive. To supply power to the rotating dome, conductive slip rings must be installed around the perimeter to ensure the slit can be opened or closed at any azimuth [2-3]. Implementing slit opening/closing with three-phase AC power requires at least three conductive slip rings, with additional slip rings needed for status detection. As remote telescope control becomes standard, it is essential not only to drive and control the slit but also to acquire its status to confirm normal working conditions for the telescope and instruments [4-8]. Traditional drive methods require numerous additional sensing elements on the slit and extra transmission channels for status signal acquisition.

This paper presents a novel circuit design that achieves slit drive control and simultaneously acquires slit status—including slip ring contact faults, slit opening in progress, and slit closing in progress—using only two conductive slip rings. Since implementation, this approach has reduced the failure rate of the slit control circuit, simplified maintenance, and enabled modular design. When the circuit is inactive, the conductive slip rings remain completely de-energized, enhancing safety.

Working Principle and Design

Traditional Three-Phase AC Drive System

Telescope domes at the Xinglong Observatory of the National Astronomical Observatories typically use three power supply slip rings to achieve slit drive, reversal, and limit control. The schematic diagram is shown in Fig. 1. While wireless methods can reduce slip ring count to three, status detection still requires additional channels. In three-phase AC motor drive circuits, the slip rings used for driving cannot be directly employed for slit status detection—this requires either additional detection channels, extra slip rings, or wireless serial communication, which may impact telescope and instrument operations. The principle diagram is shown in Fig. 2. In either case, at least one phase of the three-phase AC power supply must remain continuously energized to the slip rings, creating electric shock hazards during debugging and maintenance. More slip rings translate to higher failure rates and maintenance workload.

To address these issues, a DC drive circuit was developed that uses only two power supply slip rings to control the slit and detect its status. The drive circuit block diagram is shown in Fig. 3.

Slit Limit and Reversal Drive

Since slit opening and closing operations occur infrequently, a simple brushed DC motor circuit is selected for limit and reversal drive. The limit circuit is shown in Fig. 4, where points a and b are the terminals from the power slip rings. SQ1 is the slit open limit switch, and SQ2 is the slit close limit switch. The other end of the slip ring is the stationary power supply contact. To open or close the slit, only the polarity supplied to contact a needs to be reversed. This polarity reversal can be achieved using either relay circuits or a transistor bridge switch.

When using a transistor bridge switch, the control terminal must maintain a voltage level to keep the slit running continuously, requiring self-locking push-button switches to sustain the level. The locked button must be released before changing motor direction, which is operationally inconvenient. To simplify operation, a hybrid bridge switch combining field effect transistors (FETs) and thyristors is employed, as shown in Fig. 5.

The advantage of this circuit is its utilization of the thyristor's ability to maintain conduction after triggering. When the thyristor conducts, both its cathode potential and control electrode potential approach the power supply potential. Using this potential to maintain continuous FET conduction allows the switch bridge to be triggered by an electrical pulse. When the slit reaches a limit position, the corresponding limit switch opens, the bridge switch automatically closes, and the thyristor stops conducting. The circuit can also forcibly cut off the FET to stop slit operation at any time, making operation relatively simple.

Slit State Detection Principle

From the slit limit circuit diagram, when the slit is fully closed, applying the positive terminal of a small constant current source to point a and the negative terminal to point b results in no current flow through the drive circuit. When fully open, current flows in the opposite direction. When the slit stops at an intermediate position, current can flow in both directions from a to b and b to a. If current flows in neither direction, a power supply circuit fault is likely present —most commonly poor contact at the slip ring contacts.

By reversing the constant current source polarity and observing current direction, the slit status can be determined: current flow only from a to b indicates closed status, only from b to a indicates open status, and bidirectional flow indicates an intermediate position. This phenomenon enables status detection based on current direction.

Practical Application Circuit

A practical hybrid bridge application circuit is shown in Fig. 6. The bridge switch control terminals can be directly controlled by computer output signals. T6 and T8 are the bridge switch control terminals, while SB1, SB2, and SB3 are the bridge switch interlock circuits. T2, T3, T7, and T9 can also use non-locking pushbutton switches. For computer-controlled ports, optocouplers are selected. This bridge switch module has been successfully applied to slit control circuits at the Xinglong Observatory and has also been adopted in mirror cover drive circuits, where a single-wire delay circuit enables coordinated operation of the two mirror covers with simple wiring.

One implementation of the slit state detection circuit is shown in Fig. 7. When the slit is not being driven, the drive bridge switch is off, and the detection circuit provides approximately 5 mA of constant current to the slit drive circuit. The detection circuit is a constant current bridge switch connected in parallel with the drive bridge switch. The constant current tubes T9 and T10 are selected with high voltage tolerance to withstand the reverse peak voltage generated when the motor stops. Since the constant current bridge is designed for only 5 mA, it does not affect the drive circuit during operation. The detection circuit' s power supply voltage is half or less than that of the drive circuit, and the current limiting protects the optocoupler diodes.

When the drive circuit is active, the out1 terminal outputs high voltage, which controls the constant current bridge to remain off, enabling time-sharing operation of the two parallel bridges. When slit status acquisition is needed, the constant current bridge is activated, and the status is collected at the optocoupler output. By applying phase-opposite square wave signals to the a and b terminals, the direction-alternating constant current signal can be obtained at the out1 terminal. If the constant current signal can flow through the slit drive circuit in a particular direction, the optocoupler in the current path produces a pulsating signal.

If pulsating signals are generated in both directions, the slit is stopped at an intermediate position. If only one direction produces a pulsating signal, it indicates that the corresponding limit switch is closed, revealing whether the slit is fully open or fully closed. If no signal is output in either direction, a fault exists in the power slip rings or drive circuit, such as disconnection or poor contact. Smoothing and filtering the pulsating signals from out1 yields stable status signals for computer acquisition.

The state detection module has been applied to the 80 cm telescope at Xinglong Observatory for slit status detection and control. Table 1 compares performance before and after the retrofit.

Performance comparison before and after retrofit

Feature	Before (Three-phase Drive)	After (DC Drive)	Benefits
Remote control	Risk of motor burnout from phase loss	No phase loss risk	Safer remote operation
Secondary wiring control	Contact-based reversing module	Non-contact reversing module	Reduced maintenance
Computer interface	Requires additional interface circuits	Directly accepts computer level or contact signals	Easier computer integration
Status sensing switches	Multiple switches required	Reduced number of switches	Simplified hardware
Slip rings	5+ required	2 required	Fewer components
Fault risks	Phase loss damage from poor contact	Automatic detection of poor contact	Proactive fault detection
Status detection	Additional detection elements required	Reuses drive slip rings for detection	Channel reuse

In some cost-sensitive applications, the gear-driven rotation structure is omitted, and drive motors are mounted directly on the rotating dome to drive wheels on a circular track. Both dome and slit drives are controlled by Programmable Logic Controllers (PLCs) communicating with computers via wireless serial ports. The two-wire control and detection principle described herein can be implemented in PLCs as well. The PLC output modules should use transistor types to accommodate frequent switching operations for dynamic detection.

This drive and detection method minimizes the number of conductive slip rings on rotating domes while using the simplest reversing circuit to achieve slit drive control and status detection. Both functions share the same two slip rings, eliminating the need for separate status detection elements on the slit. Practical application has reduced slit control circuit failure rates and simplified maintenance through modular design. The self-locking bridge switch module has also proven effective in telescope mirror cover control. This approach can be widely applied to other opening/closing limit or two-end travel limit applications, improving circuit reliability while reducing wiring complexity. The circuit achieves status detection without requiring additional detection elements at drive limit positions or separate status signal transmission channels.

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Note: Figure translations are in progress. See original paper for figures.