Integration and commissioning of the China SONG Telescope Tracking System¹

RenChangzhi¹, WanHai¹, LiHeng^{1,3}, XuJin¹, WangGuomin^{1,2}, JiangXiang¹

1. National Astronomical Observatories / Nanjing Institute of Astronomical Optics & Technology, Chinese Academy of Sciences, Nanjing 210042, China

2. Key Laboratory of Astronomical Optics & Technology, Nanjing Institute of Astronomical Optics & Technology, Chinese Academy of Sciences, Nanjing 210042, China

3. Graduate University of Chinese Academy of Sciences, Beijing 100049, China

ABSTRACT

China SONG telescope would achieve the goal for long time continuous, uninterrupted, full automatic observation and works in the diffraction limit condition, what's more, it must realize 0.3 arc second tracking precision without guide star. This paper describes the integration and fine-tuning of the China SONG Drive Systems. It discusses the different problems encountered during the integration and commissioning. The servo model that was used to simulate the problems and to find new solutions is described as well as test results and advanced analysis methods.

keywords: China SONG telescope, direct drive, full automatic control, Telescope pointing system, SONG (Stellar Oscillations Network Group)

1. INTRODUCTION

SONG (Stellar Oscillations Network Group) is a Danish initiative to design and build a global network of 1-m class telescopes located at 8 existing observatories around the world, dedicated to carrying out precise measurements of stellar surface motions and brightness variations. which has been devised a new and innovative concept to overcome these limitations in a cost-effective way. The plan provides the next logical step forward in asteroseis-mology and exoplanet search. The outcome will be a rigorous test of the foundations of stellar astrophysics and vital statistics on the occurrence of low-mass planets and planetary systems around other stars. This imposes strong constraints on theories of the formation of planetary systems and gives us crucial new knowledge about how abundant extraterrestrial life can be^[1]. China SONG, as one of the eight sites, its 1-m class telescope could achieve the goal for long time continuous, uninterrupted, full automatic observation and works in the diffraction limit condition. At the same time the telescope must realize 0.3 arc second tracking precision without guide star, which is a very challenge and difficult task for 1 meter telescope tracking system . The direct drive motors and encoders form together with the control system a high performance telescope exhibiting very high tracking accuracy.

The China SONG telescope's pointing servo control loop has been tuned in the workshop in Nanjing Institute of Astronomical Optics & Technology before the transporting to the observation in Delingha, which's commissioning activity

Ground-based and Airborne Telescopes V, edited by Larry M. Stepp, Roberto Gilmozzi, Helen J. Hall, Proc. of SPIE Vol. 9145, 91453R • © 2014 SPIE CCC code: 0277-786X/14/\$18 • doi: 10.1117/12.2054702

¹ This work was supported by the SONG project (A07), the National Natural Science Foundation of China General Program (11273039) and Astronomical projects of the Chinese academy of sciences (C-113)

had a good property. This preparatory work make the job in Delingha proceed very smoothly during the telescope mounting, integration and commissioning. Some simple test has been done for the reason of time, and it sound that the telescope successfully tuned and work very well.

China SONG telescope's scientific goals not only require that it would observe the target continuous and uninterrupted in long time, but also must work in the diffraction limit condition, active optical technology and direct drive technology in its tracking system is used in the China SONG standard node telescope. Although strictly specifications has been designed in the begin stage, the following test show it is very hard during pointing process in a high speed at 20°/s. in fact, maximum pointing speed is adjusted to 10°/s by the test and tuning in the workshop.



Figure1. the tracking speed of AZ and ALT axis of China SONG telescope in Delingha Observation

Control item	Performance index +220°	notes	
Altitude axis rotation range Angle encoder resolution	0~90° < 0.01"	Azimuth axis and Altitude axis	
The Maximum stars tracking speed Maximum acceleration	$4^{\circ}/s$ $2^{\circ}/s^2$	Azimuth axis and Altitude axis Azimuth axis and Altitude axis	
Maximum pointing speed zenith blind area in the stars tracking mode	10° / s * 0.5°	No guarantee accuracy	
Pointing accuracy Repeat pointing accuracy	<5"(<i>rms</i>) <1"(<i>rms</i>)	Zenith distance $< 70^{\circ}$ Zenith distance $< 70^{\circ}$	
Stars tracking precision	<0.3"(<i>rms</i>) in 90 second <1"(<i>rms</i>) in 30 minute without guiding star		

TT 1 1 1	C1 ·	CONTO		·
Table I	(hing	SONG	main	specifications
	Canna		1114111	socemeanons

2. China SONG telescope's tracking system

China SONG telescope's tracking system is a controlled electromechanical motion system consisted of controllers, actuators (direct drive motors), sensors etc., of which the position, velocity and acceleration has to be controlled. the main hardware is shown in figure 2. Industrial PC receives telescope observation system (OCS) or remote control system's instructions through the Ethernet and instructs UMAC to control multiple servo motors to implement multi-axial coordinated motion after certain data processing. The control information is outputted by UMAC to servo amplifiers to drive and control servo motor, and form one multi-axes (Azimuth, Altitude) closed loop control system. one PCI GPS card is plugged in the IPC to receive and get accurate UTC time and geographical coordinates. the tracking target 's azimuth Angle and height is calculated by astronomical formula according to the information and the target ascension and declination coordinates, which is feed back to the telescope tracking controlling system to implement to track and point to the target.



figure 2. the construction of hardware of tracking system

3.1 Actuators & drives

Azimuth axis is driven directly by a ETEL torque servo motor TMB0450-100-3VBN and ETEL servo amplifier is matched and selected as DSC2V 164-111 X-000. What's more, in order to protect the azimuth motor to be damaged by the over-voltage of the center, one Interface Motor Spike Suppressor (IMSPS) is installed into the system, as is shown in figure 3. Altitude shaft is driven directly by a ETEL torque servo motor TMB0360-030-3 VAS, and ETEL servo amplifier is matched and selected DSC2P 144-321 X-000. Because the motor didn't have the neutral line, it needn't install IMSPS.



Figure 3. tracking control system schematic diagram

3.2 Position feedback Sensors

Position feedback information is measured by the HEIDENHAIN company's no built-in bearing angle encoder ERA 4282 C, 52000 lines, including ERA 4202 C grating drum and four reading heads ERA 4280. Encoder signals are subdivided into 4096 by ACC-51E of UMAC as position feedback signals.

table 2.	the m	nain sp	pecifica	tions of	of the	driving	hardware
						···· 0	

	AZ	ALT		
ENCODER	ERA 4280C, 52000 lines	ENCODER	ERA 4280C, 52000 lines	
AMPLIFIER	DSC2V164-111 X-000 380V	AMPLIFIER	DSC2P 144-321 X-000 220V	
MOTOR	TMB0450-100-3VBN 3PHASE	MOTOR	TMB0360-030-3VAS 3PHASE	
	88poles 44polepairs		66poles 33polepairs	
IMSPS	YES	IMSPS	NO	
CONTROLLER	UMAC	CONTROLLER	UMAC	

3.3 Control system and Electronic soft ware

The software design task mainly includes driving, pointing, tracking , data processing, man-machine interface , communication, the remote control, and so on, which is consists of PC monitoring software program , UMAC real-time control and remote control. Monitoring program communicates with other subsystem, receive instructions command and feedback state through the TCP/IP protocol. UMAC real-time control software is mainly in charge of all kinds of high interpolation, servo information update , compensation computing , data error test where real time requirement is very high. The soft system controls all the motion process of servo motor and the signal processing from I/O ports etc. The software mainly includes servo drive module, interpolation module, monitoring module, the data acquisition module.



Figure 4. the main interface of telescope tracking control software

4. THE TRACKING TEST AND RESULTS

Double/three closed loop PID control algorithm is simple and widely applied in various astronomical telescope tracking system at home and abroad, for example, VLT^[7], Keck^[8] telescopes, so as China SONG telescope in his tracking system. The tracking system's servo control properties had started well before the tuning of the telescope. Control simulations had been done during the design phase, the hardware and software had been completed, the transfer functions of the axes had been identified and some preliminary tests had been done in of workshop Nanjing Institute of Astronomical Optics & Technology before the transporting to the observation in Delingha. Nevertheless, during the telescope commissioning the tracking servo control system has to demonstrate to maintain an optimal level of performance in any possible condition. Therefore, it is necessary to perform a complete set of tests, spanning all the different conditions for axes positions and speeds specified in the design stage. This test case was always the same, allowing a direct comparison between data collected in different conditions, three different target were blind tracked by China SONG telescope, the tracking error is illustrated in table 3-5, which is shown that all is better than the 0.03 "RMS values.



Figure 5. the main interface of telescope tracking control software

Table 3 tracking error of the target 1

	Target 1: RA 12h5m47 Dec -	3d52m5.96s
	AZ Tracking accuracy RMS (")	0.0896
AZ Axis	AZ Tracking accuracy PTV (")	0.492
	ALT Tracking accuracy RMS (")	0.0114
ALT Axis	ALT Tracking accuracy PTV (")	0.107
	Total Tracking accuracy RMS (")	0.0286
telescope rack	Total Tracking accuracy PTV (")	0.151

Table4 tracking error of the target 2

	Target 2: RA	15h42m47	Dec -3d52m5.9	96s
	AZ Trackin	g accuracy RMS RM	S (")	0.0931
AZ Axis	AZ Trackin	g accuracy RMS PTV	/ (")	0.4892
	ALT Tracki	ng accuracy RMS (")		0.0123
ALT Axis	ALT Tracki	ng accuracy PTV (")		0.096
	Total Track	ing accuracy RMS ("))	0.0283
telescope rac	k Total Track	ing accuracy PTV (")		0.145

I	Target 3:	RA 16h35m47	Dec -33d52m5.96s	
	AZ	Tracking accuracy RMS (")	0.057	75
AZ Axis	AZ	Fracking accuracy PTV (")	0.359)
	ALT	Tracking accuracy RMS (")	0.01	
ALT Axis	ALT	Tracking accuracy PTV (")	0.07	
	Tota	Tracking accuracy RMS (") 0.027	/4
telescope rack	k Tota	Tracking accuracy PTV (")	0.164	Ļ

Table 5 tracking error of the target 3

Figure 6 and Figure 7 show the results of the test in terms of RMS errors, respectively for altitude, azimuth. The difference between azimuth and altitude is caused by the different speed ranges of the two axes: the maximum altitude speed at the latitude of Delingha is only about 12"/s (see figure 1), while on the contrary the maximum azimuth speed becomes much larger near the blind spot. In most of the cases the azimuth travels faster than altitude and consequently the trajectory is followed with a little loss of accuracy, especially near the zenith.



Figure 6. Example of altitude error evolution against time and axis position error during near 20 minutes tracking test. The altitude speed was v=0.1"/s, while position error _{RMS} =0.00863".



Figure 7. Example of Azimuth error evolution against time and axis position during near 20 minutes tracking test. The altitude speed was v=1500"/s, while position error $_{RMS}$ =0.07".

5.CONCLUSION

We have presented the pointing and tracking results obtained during the commissioning and integration of the China SONG telescope. After an accurate tuning, the pointing and tracking system has outperformed the specifications, however, the accuracy of the China SONG telescope's tracking system has to be proofed and verified by ultimate test.

6. ACKNOWLEDGE

The authors should like to thank Dr. YangShihai who gives us many instructed advice during tuning the telescope. We would like to thank the advanced engineer Mr. LuXiaomeng. The discussion with him on how to design the test experiment and optimize the way to improve the tracking accuracy has always been beneficial and interesting.

7. REFERENCE

1. SONG GROUP, "<u>General overview of science motivation and brief technical description.</u>" http://astro.phys.au.dk/SONG/

2.China SONG Group, "China standard node telescope system solution design specification," the national observatory, SONG CN Std -Schematic Design-V1, 2010.6.2

3. RenChangzhi, XuJin,etc. "China SONG Telescope Tracking System Based on Direct Drive Technology", Proc. of SPIE Vol. 8449,2012

4. Anton Norup Sørensen, "SONG General optical layout and functions", SONG-TRE-3400-0047, 2009.10.02

5. P.Gutierrz, "Standardization of direct drives servos in telescope applications", Proc. Of SPIE, Vol.4837,325-335, 2003

6. T.Erm and P.Gutierrez, "Integration and tuning of the VLT Drive Systems", Proc. of SPIE Vol. 4004,490-499,2000

7. Martin Ravensbergen, "Main axes servo systems of VLT", Proc. Of SPIE vol. 2199, 997-1005, 1994,

8. Mark J. Sirota, Peter M. Thompson," Azimuth/elevation servo performance of the W.M. Keck telescope", Proc. Of SPIE vol. 2199, 126-141,1994

9. Shahruz S M, SchwArtz A L, "Nonlinear PI compensators that achieve high performance", Journal of Dynamic Systems Measurement and Control [J], Transactions ASME, 105-110,1997