One direct drive system for Telescope

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ABSTRACT

The paper discusses one direct drive telescope experiment bed (DDTEB), which is designed to simulate the modern telescope tracking system. The main task is to find the problem and the reliability which might be met in the real direct drive tracking system of the telescope and how to handle them. More information and experience will be acquired and accumulated to use the direct drive technology in the telescope complex motion system of Chinese telescope in the future.

Keywords: Direct drive, segmentation, Direct Drive telescope test-bed (DDTEB), Arc PMSM,

1. INTRODUCTION

Modern large telescope will be endowed with advanced imaging systems and active optics, resulting in very high peak angular resolution. [1] What's more, the drive systems for the telescope must consequently be able to guarantee a tracking accuracy better than the telescope angular resolution, in spite of unbalanced and sudden loads such as wind gusts and in spite of a structure that, because of its size, can not be infinitely stiff. Direct drive motors are finding their way into telescope drive designs to handle the quite hard problem and have many advantages over more traditionally used friction and rack/pinion drive. The advantages include high stiffness, no friction, easy alignment adjustment and low maintenance. [2] The direct drive technology has been successfully used in the VLT and Japan's SUBARU telescope. What's more, as direct drive technology develop, it might push to more reliable and cheaper solutions for future telescope complex motion system.

The direct drive telescope experiment bed (DDTEB), as one telescope direct drive simulate experiment bed, consists of AZ drive and EI drive, which can simulate the tracking system of modern large telescope. By the DDTEB, we can not only test the property of the direct drive system but also modern control theory which might be used in the telescope complex motion system and improve the system's property.

The paper mainly explores the Arc PM Synchronous Motor (Arc PMSM)-one direct drive motor, the control system scheme and system feedback sources of the DDTEB. For some reasons, the process of the project has to be postponed about three months, the DDTEB is still being manufactured and the model is shown as figure-1. Table-1 gives the main specification of the experiment bed.

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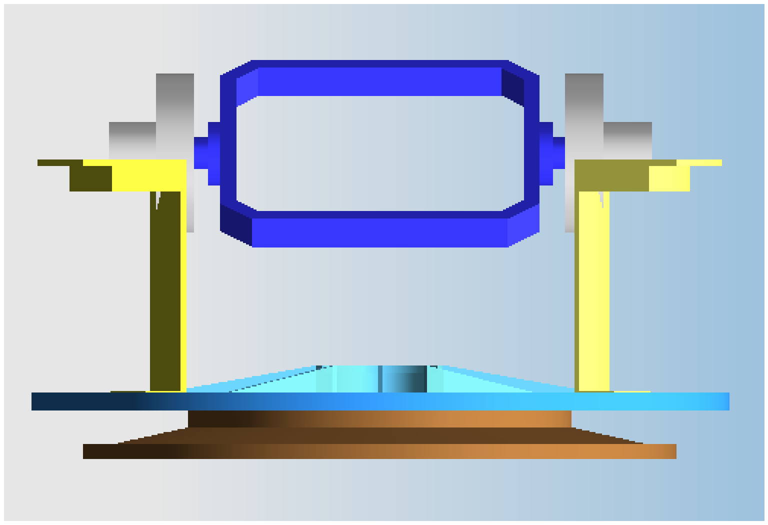

Figure-1 the model of DDTEB

Table-1 the DDTEB Specification

The DDTEB Specification	
AZ Arc PMSM Rated rms cont. torque(N.m)	12000
Speed Range	5 °~1″/s
Acceleration	≥2°/s^2
Position resolution	1″~5″

2. The Drives

Direct drive technology has been chosen as the drive solution because of its many advantages over more traditionally used friction and rack/pinion drive. However, modern large telescope requires the design and realization of such unusually large torque motors, which must be manufactured piecewise and assembled on-site. Furthermore, in spite of their very large size, the torque motors must be controlled with a very high control bandwidth and the torque slew rate must be extremely steep too. For all the reasons, it is very hard to realize such a torque motor by traditional method. An Arc PMSM is designed with a non-conventional approach for the DDTEB.

The DDTEB direct drives consist of segmented, Arc PM Synchronous Motors that are formed by:

It is a radial gap surface permanent magnet motor, 120 poles, which is consisted of 15 stator units and segmented rotor. Each unit of the Arc PMSM can be regarded as one “small powerful motor”, more units can be modified more powerful motor. The whole Arc PMSM are modified five “demanded motors” that each can meet the requirement of the DDTEB. In the DDTEB, only two “demanded motors” are mounted on the DDTEB in the view of the cost.

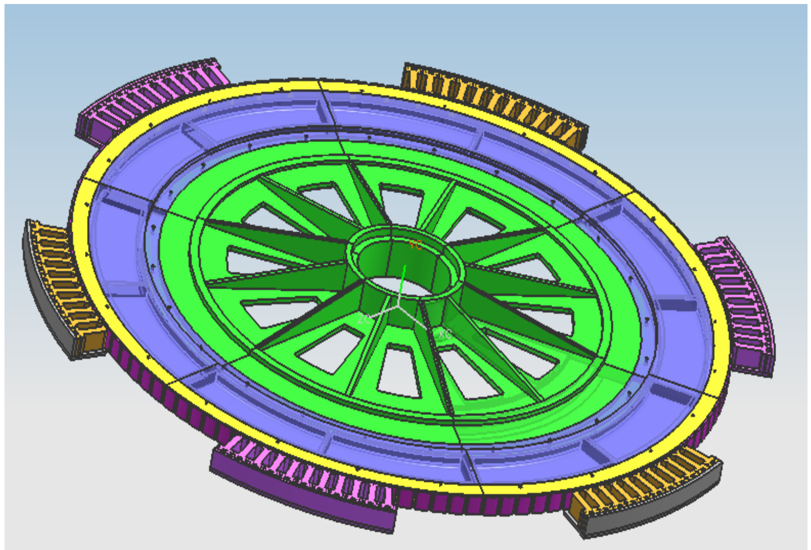

Figure-2 the Arc PMSM Model

The rotor (Fig. 2) is disc-shaped, and realized in arc segments. 120 Permanent magnets are pasted on the disc and protected by a stainless steel structure. The multi-pole field generated by the magnets is directed perpendicular to the rotor axis (YC).

The whole motor is made of 15 stator units, each surrounding an arc of the rotor disc (Fig-2). One stator unit is composed of 9 segments (8 poles) (Fig-4): Each stator unit can be regard as one “small powerful motor” and work respectively. Table 2 gives the AZ Arc PMSM Specification.

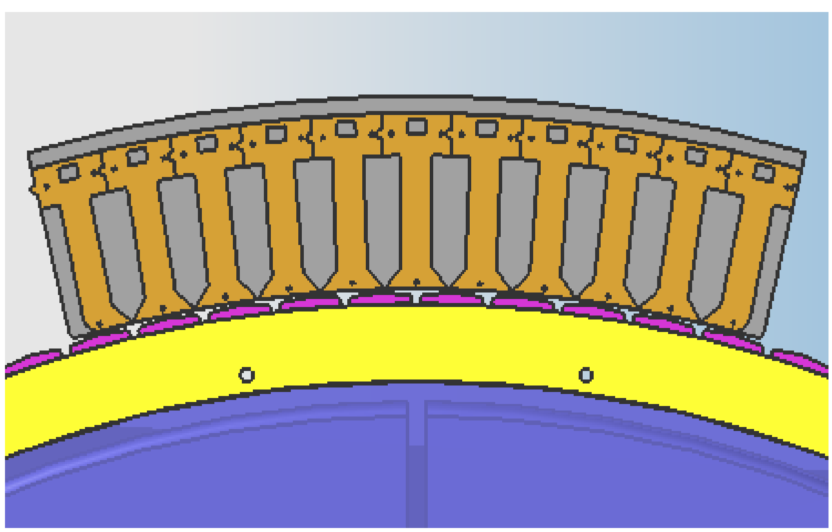

Figure-4 Section of the rotor and stator

Table 2- Arc PMSM Specification

Arc PMSM Specification	
Specification	**Azimuth Motor**
Rated rms cont. torque(N.m)	12000
Speed Range	10°~1″/s
Acceleration	≥0.0349rad/s^2
Outer diameter(m)	2.5
Motor Thickness(m)	0.1
Motor poles	120
Air gap (mm)	2.5

The proposed design for the Arc motor is characterized by a number of key advantages: The air gap (set to 2.5mm) is easily adjusted, unit by unit, during on-site installation; a stator unit can be regard as one "small" powerful motor and run respectively, more stator units can be assembled more powerful motor. Although one stator unit is out of work, the whole motor can still run normally. More units can compose more powerful motor unit; the stator unit can be removed easily because each stator unit is simple fixed on the base. Disassembly can then be carried out without need of specific tools.

3. CONTROL SCHEME

The control system of the DDTEB is consists of the central computer control system and the local controller unit (LCU), which is connected with the computer control system by RS-232 or SCI. the control system is in charge of the drive control of the AZ drive and EI drive of the DDTEB, which the control block diagram is shown as figure-5.

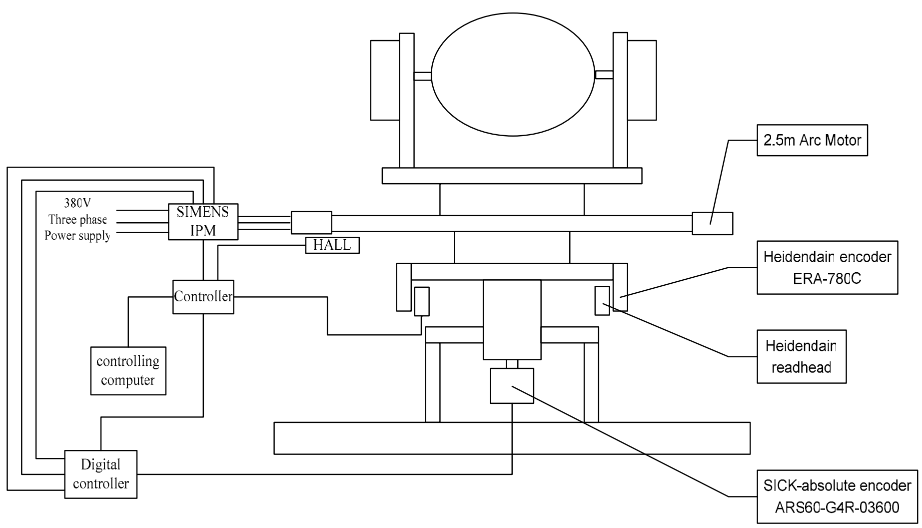

Figure-5 DDTEB Control Block diagram

3.1 LCU (LOCAL CONTROLER UNIT) Scheme

The LCU of the DDTEB is designed to control and drive the Arc PMSM. Just as it has been discussed on the text, each unit of the Arc PMSM can be regarded as one "small powerful motor" and more unit can be assembled more powerful motor unit. The whole Arc PMSM are modified five "demanded motors" that each can meet the requirement of the DDTEB, which can make the system can still run normally in case one or two are out of service. In the experiment, only two "demanded motors" are mounted on the DDTEB (see figure-2). Each motor unit or "demanded motor" is controlled by one LCU and the control information is transmitted to the central controlling system, which make the control system can monitor and control the "demanded motor" respectively with the feedback information. The LCU is used to control the modern telescope tracking system based on the direct drive. Many new idea and function may be developed to make the LCU perfect in the future. So many extend functions are reserved. The detailed structure of the LCU for the DDTEB is shown as figure-6.

For the DDTEB, the low speed is 1″/s even slower, while "high speed" can reach 2°~10°/s even faster. The range of speed is very wide (1:36000). What's more, in order to simulate modern telescope tracking system, the position resolution of the DDTEB must be higher than 1″. HEIDENHAIN EAR-780C and one 400-subdivision-reading head are used in the encoder system in order to meet such specified higher position resolution. While when the DDTEB runs in "high speed", it is unnecessary to need the 400-subdivision-reading head. So in the LCU, there is a speed inspect block by which it can handle different single by inspecting the system velocity.

The local control system mainly consists of LCU, Arc PMSM, IPM, speed sensors and position sensors. The system controls the Arc PMSM in real time and receives the control demand from central control computer and transfers the drives information to it.

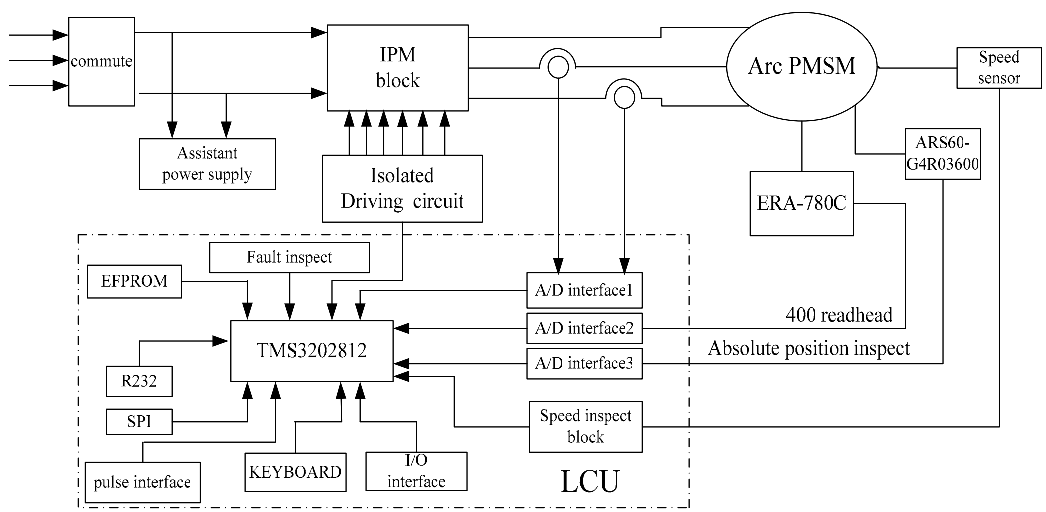

Figure-6 Detailed Servo Drive Block Diagram

The main functions of the LCU are generalized in the following text:

- **Position**

Position information is inspected by the mix encoder composed of one absolute encoder (SICK ARS-G4R-03600) and one incremental encoder (HEIDENHAIN EAR-780C and one 400-reading head). In this way the position resolution is ensured to meet the specification of the DDTEB. In addition, the DDTEB can at least get the absolute encoder resolution and it is very easy to correct the system error when the system inspects the wrong position single.

- **Speed**

Speed single is derived from tachometer or from the position by differential. In general both methods are demanded on the system. In our experiment bed, only the position differential method is considered because of the cost. In the LCU there is a velocity inspect block which can tell and handle the demanded single by inspect the range of the system's speed. A wide modulate speed range can be get by this way. In the control system of the DDTEB the modulate speed range can reach 36000.

- **Direction Commutation**

SICK absolute encoder ARS60 - G4R03600 is selected in order to ensure the servo system can get same control precision on both direction when the system works.

- **System protection**

In general many circuit protecting methods are considered in most commercial IPM , in LCU some other methods are developed to improve the safety of the system. In the control scheme, the system can work better by monitoring the single from the I/O interface and software monitoring the exception of the system such as circuit, voltage and speed.

- **Other function**

The LCU must to complete many accessorial functions, such as data transmission, single monitoring. In addition many extend function should be considered. For example, the LCU is connected with the central control computer and transfers information by RS-232 OR SCI interface, which seem to be no problem for our experiment bed. However it may be unsuitable to the real telescope tracking system for the long distance between the telescope and the control room. So some other interface which is more suitable to the future telescope should be very easy to add to the system.

3.2 central computer control scheme

Central computer controlling system is designed to monitoring the telescope in the controlling room. So, it must initial all the device parameters before the system works, when the system runs, the central computer controlling system has to handle and analysis the data from the LCU to ensure the system work normally, the system error must be corrected when deviation is found between the feedback data information and the demanded reference command. However, when the unexpected thing happens, it can stop the system immediately.

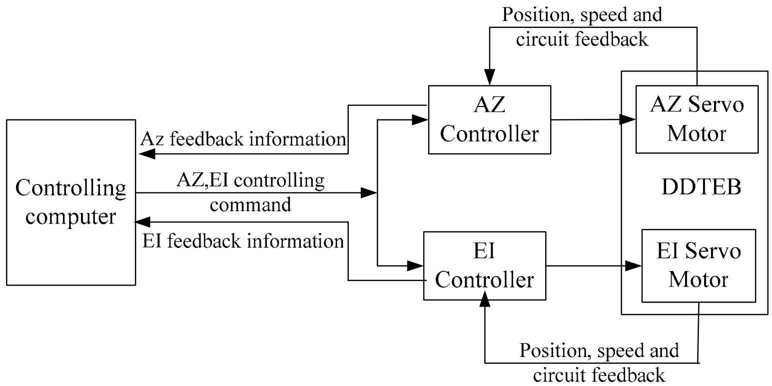

Figure-7 Detailed Servo Control system Block Diagram

4. SYSTEM FEEDBACK SCHEME

4.1 Position feedback

Modern tape encoder technology with high resolution and sophisticated multi-reading-unit system plus advanced data processing algorithm will come to play in telescope applications. HEIDENHAIN is the best tape encoder manufacturer of the world. ERA 780C from HEIDENHAIN with 1146.1mm in diameter and 90000 lines in one full circle which is selected for the DDTEB based on its successful application on LAMOST. According to HEIDENHAIN the accuracy of 0.08" RMS is reachable if the star-measurement correction is adopted with 8 reading heads.

Another product of HEIDENHAIN, an IK320V VME-Bus counter card with interpolation 4096-fold can provide interface for two reading heads. For DDTEB 4 reading heads is advised and designed in the plan. In fact only one reading head is adopted in the system for the cost consideration.

Tape encoder ring with large diameter is preferable for telescope, because the larger the diameter is, the more accurate the lines on the tape scale are. Figure-8 shows the HEIDENHAIN wrap-around scheme.

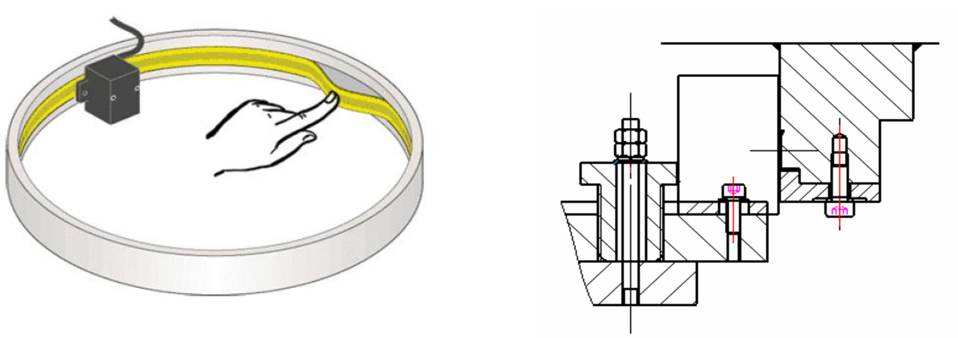

Figure-8 HEIDENHAIN (ERA-780C) wrap-around scheme

4.2 Speed feedback

Speed single is derived from the position information by differential. In the experiment bed, the position single is inspected by the encoder ERA-780C. In the LCU there is a velocity generating block which can convert the position single to speed single.

4.3 direction commutation

In the DDTEB, absolute encoder is considered to realize the two following functions:

The drives (Arc PMSM) can get same control precision when the system works and commutate the direction. So it is very important for the drives to correct the error when the system changes the running direction.

The Arc PMSM control should be considered too. It is one 120 poles motor, so the step of encoder must be the integral multiple of the pole number such as 720, 3600, 7200.

SICK absolute encoder ARS60 - G4R-03600 is selected because it is a 3600 step absolute encoder. Its single-turn is available with any desired number of steps between 2 and 32768. What's more, simple zero adjustment, excellent price/performance ratio and high reliability are regarded as good choice.

5. CONCLUSION

Direct drive may push to the best solutions for future large telescope complex motion system., The direct drive telescope experiment bed (DDTEB), as one telescope direct drive simulate experiment bed, give us a way to study and handle problem which might arise in the real telescope direct drive system. For the time been, and because of many of time delays, the DDTEB is still under mounted and tested, so many major tests for this paper have not been finished yet. However, after the experiment bed works normally, an important knowledge will be collected and a better understanding of which is benefit from the drive technologies.

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7. REFERENCE

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