International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 3 Issue 1, January-2014, pp: (114-119), Impact Factor: 1.252, Available online at: www.erpublications.com

Implementation of Servo Drive System for Remote Sensing Satellite Ground Station

Heera Singh R[1], Dr. Rami Reddy B[2], Chandrasekhara Rao B[3], Satyanarayana M[4]
[1,3,4]Indian Space Research Organization, National Remote Sensing Centre, Balanagar, Hyderabad.
[2]Professor of Electrical & Electronics Engineering Department, Pondicherry Engineering College, Puducherry, India

Abstract: In this current article, the current control technique of servo motor for antenna control ground station is realized, implemented in simulation and dealt in detail. Motor considered is a Permanent Magnet Servo Motor, current control methodology is based on a common DC signal; impacts and dynamic behavior of control strategy brought out for detail illustration of test farm. The system was constructed and the results were found to be compatible with practical ground station systems. All the components like inverter, Servo motor and speed control blocks have been built mathematically. For current control strategy based on common DC signal, sensors are used to sense the motor currents; these currents are compared with reference currents to get required error for controlling servo motor drive. This error is compensated in PI controller and is compared with the triangular wave to produce the desired pulses. In this way the amplitude of the signal is regulated in a closed-loop manner by sensing the output currents and comparing with reference currents. The program selected for implementation of this method is PSIM software tool. Further, as the any antenna system will have the back-lash in gearing mechanism of an AZ over EL Mount Antenna, to minimize back-lash, two motors are required, and to drive motors, two drive amplifiers also required. Hence, Dual drive control mechanism of antenna drive system is illustrated in detail.

Keywords: Back-lash, Dual Drive, Feedback Current Control, PSIM Software.

Introduction

The rapid population growth of the world and the associated changes in the distribution of people has resulted in a rapidly rising toll of deaths and economic consequences from natural disasters. Imagery acquired by airborne or satellite sensors provide an important source of information for mapping and monitoring the natural and manmade features on the land surface. Hence there is an increasing demand for precision servo drives for tracking low earth orbit satellites for the various Remote Sensing applications in the world, which require very high velocity, acceleration and tracking accuracy.

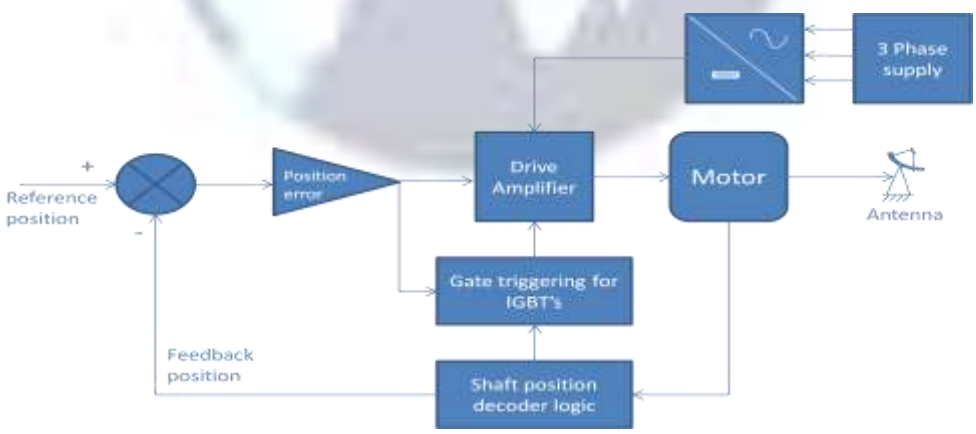

Figure 1: Physical block diagram of servo drive system

At Satellite Data Reception Station/ National Remote Sensing Centre, data is received continuously from Remote Sensing Satellites in a round the clock operations. Antenna drive control is one of the major and critical subsystems. The antenna is controlled by Servo Controlled System which mainly includes a Controller, Power Amplifiers/ Drive systems and Servo Motor. The servo drive uses either voltage or current feedback in order to obtain characteristics like high tracking accuracy, velocity and acceleration.

In this paper, current as feedback element in servo drive is realized, simulated and compared the results with practical and also with other possible current control methods. The advantages of current control of motor drive using a common DC signal as reference is illustrated in detail. The dis-advantages of other controls can be overcome by using the current control strategy of servo motor drive based on common DC signal [3], [5], [6], [7]. This Current Control strategy is implemented in PSIM software. The behavior and performance of this strategy is verified with practical systems at ground station. Such system physical block diagram is as exhibited in figure-1.

Drive Commutation and PWM Requirement

To control the speed PWM is required. To vary the speed the Hall output signals should be pulse width modulated. When the signals marked by PWM switches ON or OFF according to the sequence, the motor will run at the rated speed [1]. The PWM frequency should be at least 10 times of the max. frequency as thumb rule. By varying duty cycle, the stator voltage can be increased causes increasing of the speed. For example, machine rated speed 1000rpm, commutated with 6 pulses, the required frequency f= 1000×6 = 6000 pulse/min. Therefore, speed in pulse/sec= 6000/60= 100 Hz. And the PWM frequency= 10×100 Hz = 1 kHz. Thus the speed depends on the input voltage variation due to duty cycle variation. Hence, the servo drive is also termed as adjustable frequency drive, variable speed drive, inverter drive and also an AC drive. By varying duty cycle PWM frequency varies and switching speed also varies. This commutation process is called electronic commutation. Accordingly, the commutation sequence for six steps of commutation of IGBT is implemented, each step conducts for 60 deg of movement of motor shaft, so that combining all six steps of conduction results into 360 deg rotation in motor shaft [8], [9]. Such drive basic functional block diagram is as exhibited in below fig-2

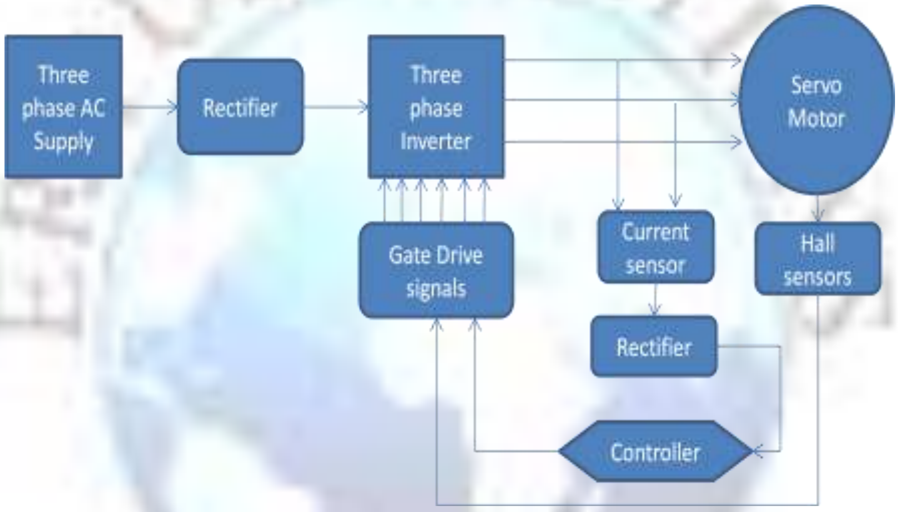

Figure 2: functional diagram of drive system

From the block diagrams, 3 phase voltage source inverter which is used to feed quasi square wave currents to the brush less DC motor [2]. Hall Effect sensors are used to sense the position of the rotor and a logic circuit is used to decode the position of the rotor and hence produce pulses for the next position of the motor. The armature currents are sensed using the current sensors and rectified using a diode bridge rectifier and the maximum value of current is found and sent to the controller. The controller compares the reference current with maximum value of current obtained and generates the error. This error is processed through a PI controller and using triangular wave, pulses are generated by using pulse width modulation [4]. Thus the gate drive circuit will be generating pulses and triggering the IGBT's and controlling the motor based on the input errors by generating the gate triggering pulses as shown in the figure-2.

Drive Current Control Strategy & Implementation in PSIM Software

The current control has inherently two loops and hence the complexity increases and thus the cost and also the power loss. It is important to mention here that to avoid these drawbacks, a simple method in which the equivalent DC current is obtained by sensing the armature currents. The DC component obtained corresponds to maximum amplitude I_{max} of the original phase currents is obtained. This component is then used to drive the motor. In the present day systems voltage control strategy is used. Current control is found to be more sensitive to changes in load compared to voltage control method. Hence a simple and efficient current control strategy of Servo (Brush Less) motor which can be utilized at satellite ground station has been done. The implemented system is as given in figure-3.

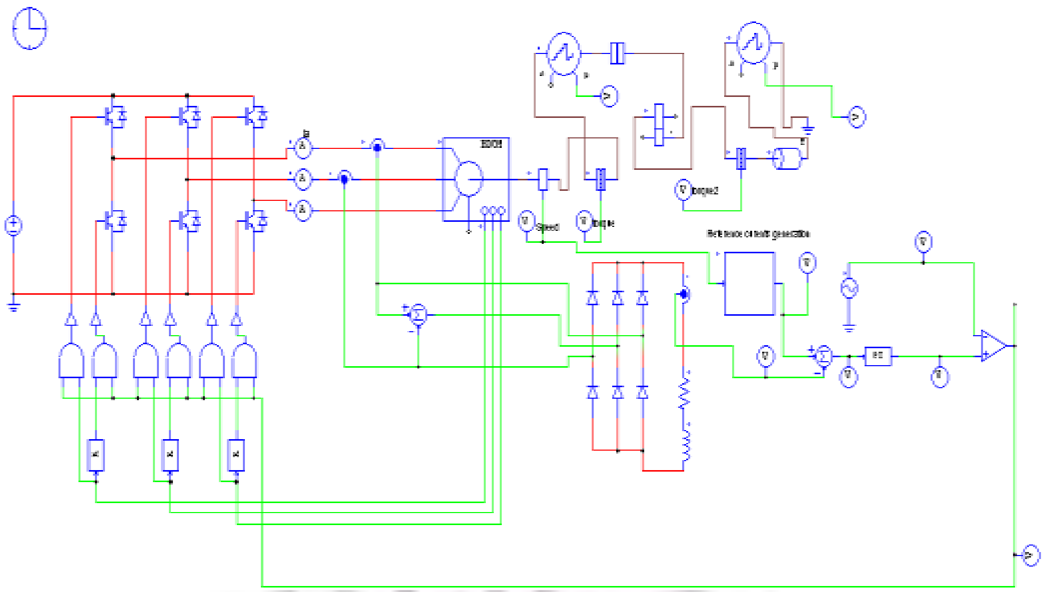

Figure 3: Implementation of Servo Drive control system in PSIM Software

The position decoder logic circuit is implemented after sensing the motor shaft position. This is important to establish proper motor commutation. Position encoders are used near the motor and also at load in the system in order to measure the position. Simplified C block is used to generate the reference currents. The load used here is a constant torque load (antenna). The effects of wind abnormalities are ignored.i.e. the wind is falling on antenna reflector at constant velocity of about 16m/sec.

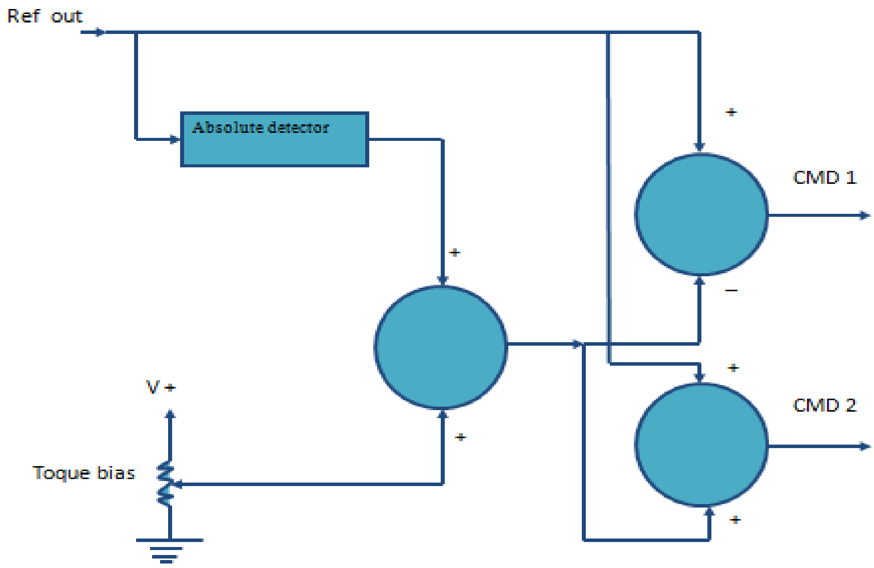

Figure 4: Linear fade out speed loop

The torque produced by motor is given to the gear box. The gear box amplifies depending on the gear ratio. This required torque obtained from the gear box rotates the antenna in respective axis. When implementing this system practically a mechanical coupling is required to couple the motor shaft and gear box. Each axis (Elevation and Azimuth) will have independent drive systems and dual drives in each axes. Dual drive mechanism is required to avoid the back-lash in gearing of antenna system. Thus the axis will have two drive amplifiers and two motors in each axes, the torque-biasing is in linear fadeout fashion as exhibited in figure-4. The biasing circuit shows that the output command/ torque of motor of the same axis should be biased before delivering the final torque to antenna. To get the final out put commands to motor, the biasing voltage will be added to one motor and subtracted from another motor.

Thus two motors operate in counter-torque mode to avoid back-lash and also to avoid possible ringing in position loop of antenna system [10]. For simulation purpose, only one motor is considered for analysis and clear understanding. The Servo drive control flow chart for an antenna drive system comprising torque biasing mechanism is as illustrated in the below figure-5.

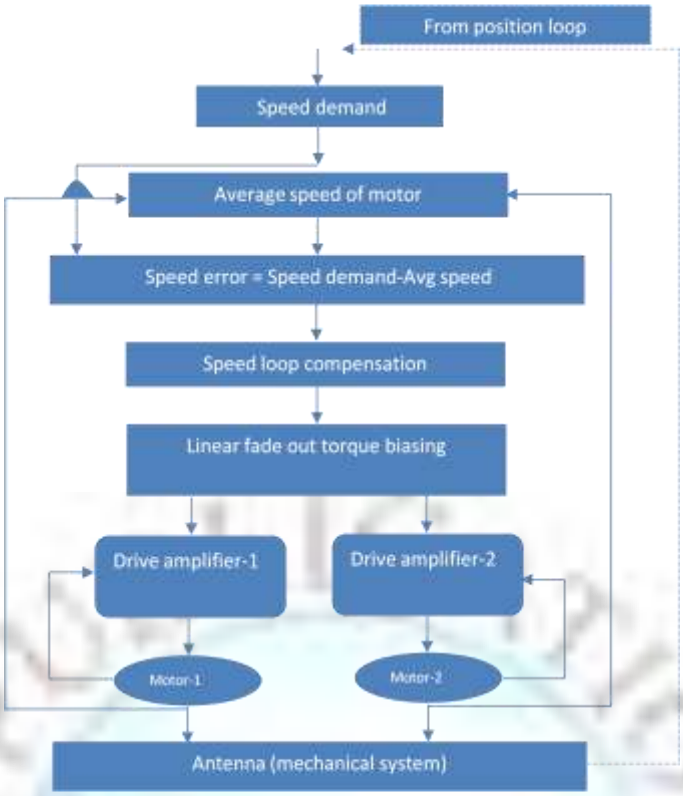

Figure 5: Servo dual drive control flow chart

From the flow chart, the inner most loop is current loop which is incorporated in drive amplifier. The motor torque is proportional to the current and hence the purpose of current loop is to provide a constant torque drive. The PWM inverter driving the 3 motor windings of the 3 phase AC servo motor generates winding voltages proportional to the command, in synchronization with rotor position. The output of current loop forms input to PWM inverter thus adjusting the motor voltages until measured current is equal to demand current [11]. Each motor / amplifier has its own current controller. Hence there are two current loops per axis. The sensed motor current is subtracted from the demand current and filtered through a PI controller and fed to the PWM amplifier. The current demand is fed from the outer speed loop. The input to speed loop is from outer position loop. Hence a speed error causes motors to accelerate or decelerate- the rate of acceleration is proportional to magnitude of speed error.

TABLE- 1

Maximum speed	6000rpm
Continuous stall torque	9.8Nm
Rotor Polar moment of inertia	0.00075Nm
Torque Constant line-line(kt)	0.42Nm/A
Resistance line -line	11.9ohms
Inductance line-line	2mH
Mechanical Time constant	1msec
Motor weight	11.4kg
DC voltage /1000rpm	3V
Gear Ratio	1350:1

With these design specifications, simulation test is carried out efficiently and the results were found to be good enough for predicting the practical variables. For optimizing the practical system it was very much useful in analyzing and realizing the system behavior and optimizing the system accordingly. The readings of the practical system are given in the table-2 for different angles and it can be seen that the simulated current readings and practical system readings are almost close and same. The results are also on par with the design calculation.

Results and Analysis

From the obtained results, it is concluded that the speed is about 3500rpm at normal rated conditions. The time taken by the system to reach steady state is very less and hence concludes this system is preferred compared to other possible current control strategies like HCC (hysteresis current control) etc., as this control is having several dis-advantages as noted from listed literatures. The corresponding three phase current waveforms, speed, torque, six pulses to IGBT's along with the position of the motor and load recorded from encoder were as exhibited below:

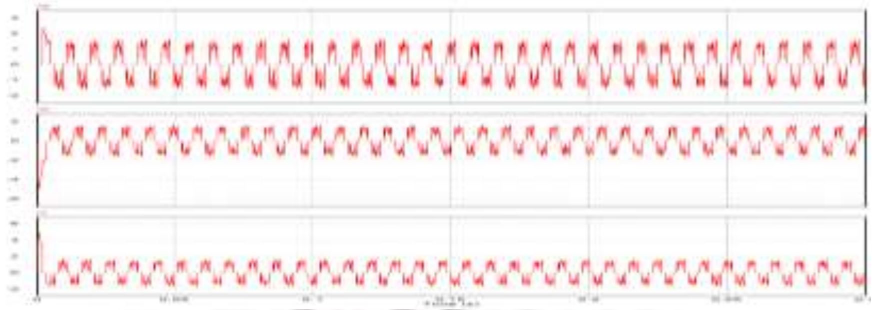

Figure 6: Three phase current waveforms

Figure 7: Speed and Torque of Motor

Figure 8: Six Pulses given to IGBT

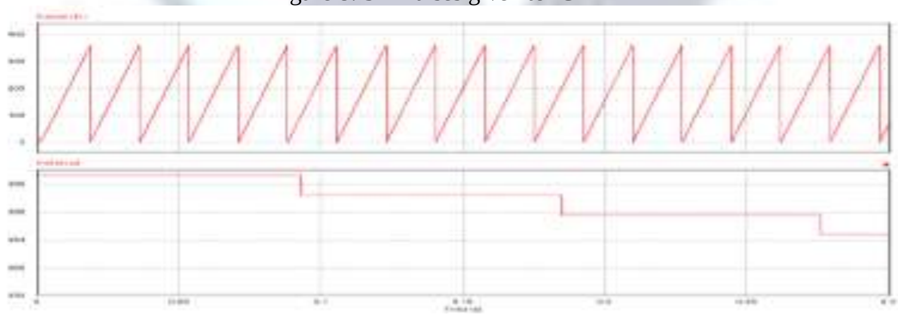

Figure 9: Position of Motor and load

From these results we can clearly see that the obtained graphs and readings are good enough to meet the design requirements and for flexible operations of motor as required. Further, results are clearly seen and understood that it is a simple and efficient control mechanism for a servo machine to control the antenna system. The advantages of this strategy mainly include: *Very simple control scheme & dynamic in behavior; Phase currents are kept balanced; Current is controlled through a single dc component. Hence, over current's protection is eliminated.*

It is very important to control the torque/ current of antenna system because wind abnormalities always will be there on reflector, to protect reflector from wind gusts this current control strategy will be eliminating the over currents problem.

TABLE-2, COMPARISION

As per simulation results		Practical
Angle (Deg)	Current (A)	Current (A)
360	1.38	1.2
355	1.2	1.3
350	1.37	1.5
345	1.45	1.6
340	1.5	1.7
335	1.5	1.9
330	1.5	2.0
325	1.5	1.9
300	1.5	2.1
280	1.5	2.2
200	1.5	1.9
150	1.5	1.6
100	1.5	1.6

From the table, the practically recorded results at ground station are very closer to simulated quantities; little variations are observed in between these simulated and practical readings because, practical system will be having dynamic variations in ambient environment. Hence, the simulated and recorded results are same in principle.

Acknowledgment

The work described in this paper was carried out at Servo Systems laboratory at Satellite Earth Station, NRSC. Authors gracefully acknowledges to servo staff who directly or indirectly involved in this work.

Conclusion

The performance of servo drive system (dual drive) using PWM inverter is realized, implemented and results were obtained with a view to improve the output torque and speed response characteristics. The torque ripples are reduced. The methodology to control the dual drive system is presented in detail; the results are compared with optimized and practically recorded results at ground station. This current control strategy has been compared with conventional control methods and proved better in performance and shown the excellent characteristic of this modulation technique. The commutation logic, position sensing for triggering IGBT's is implemented. The results show the good quality of waveforms under steady-state and transient conditions. Very simple and dynamic control strategy as the PWM variation depends on a common DC signal. Hence, circuitry becomes less in size and more economical and involved protections from balanced currents and over currents. It is concluded this is the way to approach for any practical systems optimization by obtaining, predicting and understanding the behavior of system during steady state and transient conditions and to know the performance and design verification of drive mechanism. The dual drive control mechanism for controlling antenna servo system by minimizing the back-lash is presented efficiently.

References

[1]. P. Pillay and R. Krishnan Research on drives: IEEE Trans. Ind. Applications.,1991 vol. 27, pp 986–996.
[2]. N. Hemati and M. C. Leu . Brushless dc motors: IEEE Trans. Ind. Applications., 1992 vol. 28, pp 172–180
[3]. J. Dixon, S. Tepper, and L. Morán (1996). Current-controlled voltage source inverters," Proc. Institute of. Electrical. Engineers. vol. 143, pp 301–306
[4]. C.C.Chan and K.T.Chau (1997). On overview of power electronics: IEEE transactions on Industrial Electron ,vol 44,pp 3-13
[5]. Pillay P, Krishnan R. Modeling, simulation, and analysis of permanent-magnet motor drives, Part_: The brushless DC motor drive. IEEE Trans. on Industry Applications, 1989, 25(2): 274-279
[6]. Evans P D, Brown D. Simulation of brushless DC drives IEE Proceedings B, Electric Power Applications 137(5): 299-308.
[7]. Rene Spee, Alan K. Wallace and Joel Davis. Modeling of brushless dc drive systems with pulse-width modulated excitation, Mathematical and Computer Modelling, Volume 11, 1988, Pages 1166-1171.
[8]. J. Figueroa, C. Brocart, J. Cros and P. Viarouge. Simplified simulation methods for polyphase brushless DC motors. Mathematics and Computers in Simulation, Volume 63, Issues 3-5, 17 November 2003, Pages 209-224.
[9]. Dian-sheng SUN ,Xiang CHENG,.Research of novel modeling and simulation of BLDC motor control system .
[10]. R. Heera Singh, B. Rami Reddy, Design of High Efficiency Compact Ground Station Antenna for Remote Sensing Satellites; IEEE- -5th International Conference-CODEC-2012.
[11]. R. Heera Singh, B. Rami Reddy, Design and Implementation of Antenna Control Drive system for Remote Sensing Satellites; International Journal of Electrical Engineering & Technology (IJEET), Vol.4, Issue-4, July-August 2013, Pages 93-100.