National Centre for Radio Astrophysics

BLDC INSTALLATION MANUAL

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Objective: Document collates all necessary and relevant information related to BLDC system installation which is being pursued as part of GMRT upgrade

Revision	Date	Modification/ Change
Ver. 1	28 May 2012	Initial Version

Executive Summary

This document collates all necessary information required for commissioning and validating of BLDC system in GMRT Antenna.

The First BLDC system was put in Antenna C04 after a substantial period of testing and evaluation at set-up and antenna by team which included internal members (GMRT-NCRA) and industry experts in motion control (M/s Maccon GmBH).

This report presents the various tests carried out to prove the efficacy of the Brushless System in terms of functionality in meeting the servo needs of the GMRT antenna and its aptness in interfacing to the existing Servo Computer and Interlock system. It also tries to present the RFI compliance of the system.

Contents

List of Tables

List of Figures

1. Introduction

1.1 Motivation of work

The old GMRT servo system is based on DC Servomotors which have been in use for over two decades. The increasing trouble of maintenance and the obsolescence of the system have induced the need to change to a new drive system. The new system is based on Brushless motors. Overview details of old servo system is given in [1]

Upgraded GMRT servo system replaces four brushed motors with brushless DC servo motors of Kollmorgen make. New motors used weigh one fourth of old motors which helps ease work of commissioning the motor on Azimuth and Elevation platform. These motors use electronic commutation which overcomes disadvantage of periodic maintenance required for brushed motor which uses carbon brush and commutator assembly.

Kollmorgen make brushless motors are controlled by digital drives of Kollmorgen make. Drives used are compact and software controllable. It provides human interface which can be used for configuring type of motor being used, commutation technique etc. Drive houses the current loop of servo system and provides current required to drive the motor depending on load requirement.

Speed loop of new servo system is governed by Programmable Multi Axis Controller (PMAC). Controller has DSP processor on board and is capable of controlling 8 axes at a time. GMRT servo system uses four axes to control four brushless motors. Backlash compensation algorithm to overcome play introduced due to spur gear arrangement is also implemented in PMAC. Controller also provides interactive graphical user interface. It can be configured using GUI as per system requirement

The main advantage of this upgrade is that BLDC system does not require periodic maintenance which was done in brushed motor system.

<u>1.2 Structure of Report</u>

   The basic structure of the report consists mainly of four parts. First part gives overview of complete step by step procedure followed in commissioning BLDC system.

Second part gives details about pre installation checks carried out in PMDC based antenna system.

Part3 explains system installation procedure. It describes drives and controller assembly in RFI shielded rack in detail. Followed by this it gives information about interfacing existing servo station computer (Which houses position loop) and interlock system with new BLDC system.

 Fourth part gives details about post installation check carried out in BLDC system antenna to validate whether new system installed adhered to specifications and standards of GMRT servo system

2. Installation procedure overview

Installation procedure is broadly divided in to three steps as mentioned below. Overview of these steps is given in this section. Details are mentioned in subsequent sections of this document.

A. Pre Installation checks to be performed in PMDC(Permanent Magnet Direct Current) brushed motor system

B. System Installation steps for BLDC system

C. Post Installation checks of BLDC system

A. <u>Pre Installation:</u>

1. RFI test:

    RFI test is done to check radio emission levels of existing system.

2. Motor run test:

    Perform 'RUN Test' in Manual/Local mode for both Azimuth and Elevation axis and measure current and speed as per format enclosed (Refer Table1)

3. Interlock test:

    Check all the limit switches in both axes for functionality and safety as per format enclosed (Refer Table2)

4. Locked Rotor Frequency (LRF) and Step response test in velocity loop:

    Perform LRF and step response test in the PMDC system, analyze data and note down the parameters (Refer Table3)

5. Step response test in position loop:

    Perform step response test by giving position step from control room and note down the parameters (Refer Table4)

6. Tracking test:

    Perform tracking test as mentioned in section 3.5

B. System Installation

1. Prepare cables required for rack internal wiring as per section 4.2.1

2. Carry out Electronic Cabinet (EMC) assembly for BLDC system as per section 4.2.2

3. Remove old Tacho and Power cables going from Antenna base along concrete wall to AZ & EL platform, PMDC brushed motors and Round shell connectors(RSC)

4. Mount new brushless motors on both Azimuth(2 nos) and Elevation(2 nos) platform

5. Lay new 100m long Motor Power(2 nos) and Resolver cables(2 nos) along the concrete wall from BL motor's to Antenna base

6. Route the new cables along the wall and clamp them. Ground the shield of new cables laid for BL motors every 20 meters

7. Remove Azimuth and Elevation Amplifier racks from GI room. Control rack is to be retained in its place as 86 system and SSI is housed in it

8. Remove 13.5 KVA old transformer (4 nos) from GI room and move them to Ray Shed

9. Install new transformer (15KVA) behind GI room

10. Shift the wired and assembled Electronic Cabinet (EMC) in GI room. (After testing in Laboratory(Jogshed))

11. Install 24V/15A linear DC regulated power supply in GI room along with existing 110V/24V supply

12. Installation of GI cable duct on GI room for entry of cables coming from Antenna top into GI room for EMC

13. Solder/Crimp the EMC circular connector from M/S Intercontec to all the cables laid at both the ends

14. Do modifications in Control rack as per section 4.3

15. Interface BLDC system with Control rack as per section 4.4

C. Post Installation:

1. Motor run test:

   Perform 'RUN Test' in Manual/Local mode for both Azimuth and Elevation axis and measure current and speed as per format enclosed (Refer Table15)

2. Interlock test:

   Check all the limit switches in both axes for functionality and safety as per format enclosed (Refer Table16)

3. Locked Rotor Frequency (LRF) and Step response test in velocity loop:

   Perform LRF and step response test for the BLDC system analyze data and note down parameters in Table 17

   Comparative results should be similar pre and post installation

4. Step response test for position loop:

   Perform step response test by giving position step command from control room and note down the parameters in Table18

5. Tracking test:

   Perform antenna tracking test as mentioned in section 5.3

6. RFI test:

   RFI test is done to check radio emission levels of new system.

3.   Pre installation procedures

3.1   <u>RFI test:</u>

Scope of test:

RFI test is done to check radio emission levels from old antenna system. Results obtained are kept as reference and compared with RFI test done for BLDC system post installation

Procedure:

Test is done by RFI/OFC group. For details please refer [4]

3.2   Motor run test

Scope of Test:

Motor run test involves checking Tacho and current values for different voltage inputs. These readings can be compared with 'motor run test' readings done after BLDC system has been installed.

Equipment's used: Digital multi-meter

Procedure:

1. Antenna setup is as shown in Figure1
2. Put antenna in manual mode using switch on servo system console.
3. Assure that speed pot on console panel is pointing toward zero
4. Release brakes of axis you want to perform test (Azimuth or Elevation)
5. Connect DMM probes to I/P HI pins on monitor card
6. Rotate pot on console till DMM shows 1V
7. Note down tacho and current readings in Table1 by connecting DMM probes to Tacho-HI and current points on monitor card
8. Note down current and speed shown by HHT in Table1
    Commands to check tacho and currents in HHT:
    M, D
    D (It will show currents for M1, M2, M3 and M4)
    Press '/' key
    (It will show speeds for M1, M2, M3 and M4)
9. Repeat steps for different I/P HI voltage
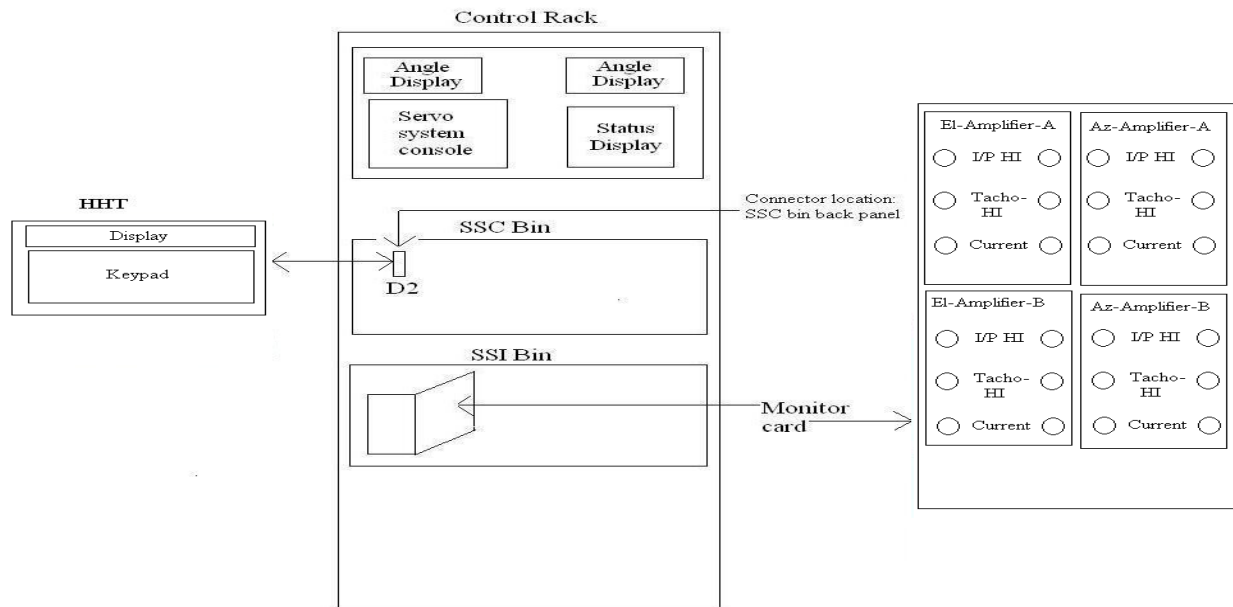
Figure1: Motor run test setup

Antenna: …………………   Date: …………….

Azimuth/Elevation

Table1: Motor run test

I/P (Volts)	ANT DIR	M1 Tach V	M 2 Tach V	M 1 Cur. mV	M 2 Cur. mV	Amp1 A	Amp2 A	HHT Cur. 1 A	HHT Cur.2 A	HHT Spd1 Rpm	HHT Spd2 Rpm
1V	CW										
2	CW										
3	CW										
4	CW										
5	CW										
Max	CW										
1	CCW										
2	CCW										
3	CCW										
4	CCW										
5	CCW										
Max	CCW										

NOTE:

For input voltage: 1V to 5V: Operate in manual mode

For maximum input voltage: Use HHT in Local mode

Hand Held Terminal commands used:

M,C

H,A (Hold command to Azimuth axis)

P,A,deg:min:sec (To give position command)

3.3 Interlock test

Scope of test:

Interlocks are used in antenna for its fail safe operation. Interlock test is done to check status of limit switches (whether it is working or not) and position where limit hit occurs. Test is done again after BLDC system has been installed to check if there is any damage after BLDC installation.

Procedure:
1. Figure2 shows limit recovery card mounted in control rack which shows limit hit indication
2. Put antenna in manual mode using switch in servo system console
3. Release brakes of axis (Azimuth or Elevation) for which you want to perform Interlock test.
4. Rotate antenna by adjusting manual input pot to full scale. Antenna will rotate and hit pre-limit and stop the Antenna by applying brakes. This will be indicated by blinking red led in limit recovery card
5. To move further to hit final limit you need to bypass pre limit. Pre limit switch can be bypassed by keeping it continuously pressed on limit recovery card. To start antenna rotation bypass pre limit switch and release brakes. Antenna will rotate further and hit final limit. Limit hit will be indicated by red led blinking
6. Follow this procedure for all interlock limit switches and note down remarks in Table2.1 and Table 2.2
   Note: Limit switch will also be indicated on status display

Figure2: Limit hit indication in Limit recovery card for Interlock test

Table2.1: Elevation interlock limit switch test

Sr No.	Limit	Remarks	Position
1	15P	OK/Not OK	
2	15F	OK/Not OK	
3	110P	OK/Not OK	
4	110F	OK/Not OK	
5	STP	OK/Not OK	
6	90D	OK/Not OK	
7	IN1	OK/Not OK	
8	IN2	OK/Not OK	
9	REL1	OK/Not OK	
10	REL2	OK/Not OK	
11	MOVL1	OK/Not OK	
12	MOVL2	OK/Not OK	
13	AOVL-EL	OK/Not OK	

Table2.2: Azimuth interlock limit switch test

Sr No.	Limit	Remarks	Position
1	+ 270P	OK/Not OK	
2	+270F	OK/Not OK	
3	-270P	OK/Not OK	
4	-270F	OK/Not OK	
5	ZERO Deg	OK/Not OK	
6	CWRAP	OK/Not OK	
7	MOVL1	OK/Not OK	
8	MOVL2	OK/Not OK	
9	AOVL-AZ	OK/Not OK	

3.4 Locked rotor frequency test and step response test in velocity loop

Note: Details of this section are referred from [2]

LRF test for velocity loop

Scope of test:

LRF is the first anti-resonance frequency in the bode magnitude plot of the system, at which, the load appears to resonate as if the motors were blocked. It is desired for a stable servo system that the LRF must lay far beyond its operating bandwidth.
Following test is done to check at what frequency LRF appears.

Brushed motor (PMDC) system
Requirements:

  1. Signal generator HP 8116 A
  2. Hand held terminal (HHT).
  3. Grounding cable for AIO card.
  4. Tool kit with jewel set screwdriver.
  5. Laptop with Lab view
  6. NI daq card 6221
  7. USB cable (To connect NI daq card with laptop)
  8. Shielded cable with probes at one end and open wire terminals at other end (To connect NI daq card to the Tacho output).
  9. BNC connector cable with other end having parallel channel arrangement

Procedure:

Note: Figure3 below gives connection details of test setup for doing LRF experiment

  1. Connect the USB-6221 cable to the input of NI daq card and laptop
  2. Connect the BNC connector end of the parallel cable to the   signal generator and one probe end to the Counter torque card (CTQ card) Azimuth test output (ground - red). Connect the open end of wire to the pin No 1 and 3 of analog input of NI daq card.
  3. Connect open wire end of parallel shielded cable to pin #4 and #6 of analog input NI daq card and probe end to the Tacho HI terminals (ground - black) of Azimuth amplifier A and monitor card.
  4. Switch off the rack power. Remove the FRC connector of the AIO card of SSC bin and connect the FRC connector end of the grounding cable to this. Connect the other end of the grounding cable to a suitable grounding point.
  5. Connect the HHT to the D type connector (D2) of the SSC bin.
  6. Switch the antenna to LOCAL mode.
  7. Give a HOLD command to the antenna from the HHT as

H, A

8. Make the Labview settings as follows:

8.1. Open lab view →New Project→Add step→Acquire Signal→Daqmx acquire→Analog input→Voltage. This will open Supported physical channel window with Dev (USB 6221) data channels.

8.2. Selectai0→ the OK. This will open Configuration window. Select Terminal configuration as RSE (Reversible single ended).

8.3. Recheck NI daq card connections using Connection diagram.

8.4. Select Step setup→ Select Channel settings→ Select Add channels or click +→ Voltage →select ai1 →Click OK →SelectTerminal configurationas RSE.

8.5. Press Record→ Select Select all to record both input and output and name the log appropriately and press OK.Enable the signal generator.

8.6. Go to Data view→ Right click and select Add signals → Select all signals.

8.7. Record for appropriate duration. Then, select Exportto→Excel sheet. This will open MS excel sheet with the data values. Save the .xls file accordingly.

8.8. This file can be later used to analyze the data.
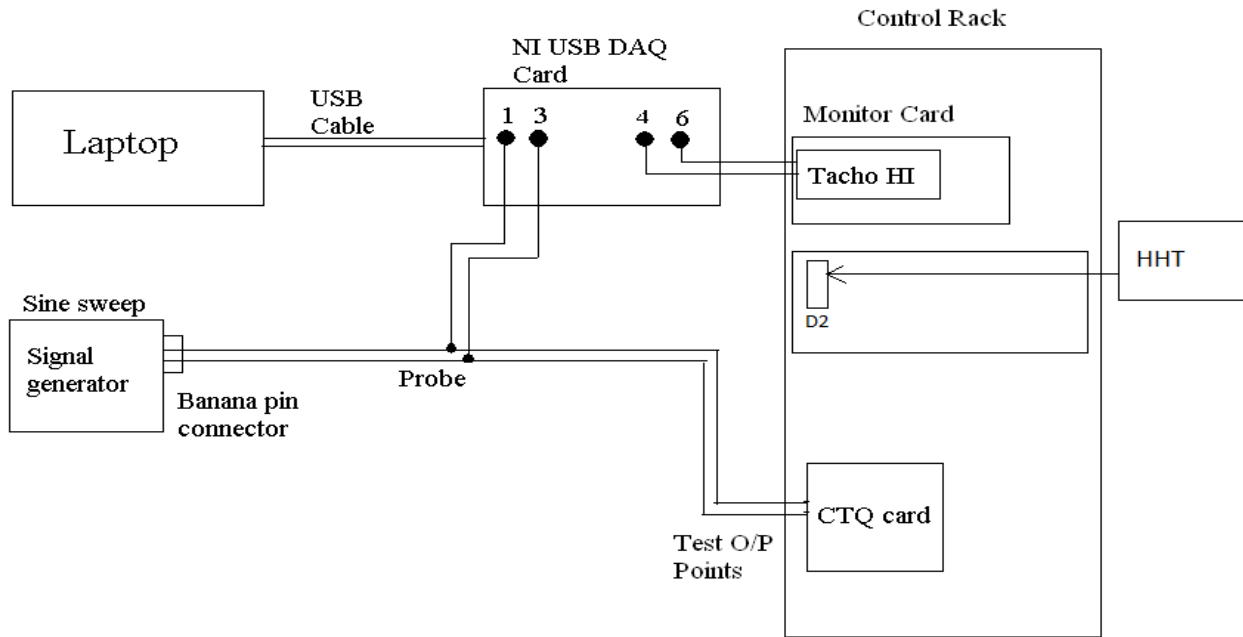
Figure3: Block diagram of LRF test setup

Table3: LRF test results

Parameters obtained from LRF test				
			Actual	Expected
1	Locked Rotor Frequency	Fr		1Hz

Step response test for velocity loop

Scope of test:

Step response test is performed to understand transient behavior of velocity loop for step command given

Requirements:
1. Signal generator HP 8116 A
2. Hand held terminal (HHT).
3. Grounding cable for AIO card.
4. Tool kit with jewel set screwdriver.
5. Laptop with Lab view
6. NI daq card 6221
7. USB cable (To connect NI daq card with laptop)
8. Shielded cable with probes at one end and open wire terminals at other end (To connect NI daq card to the Tacho output).
9. BNC connector cable with other end having parallel channel arrangement

Procedure:

Note: Figure4 below gives connection details of test setup for doing step response experiment

1. Connect the USB-6221 cable to the input of NI daq card and laptop
2. Connect the banana pin end of the parallel cable to the power supply output and the probe end to the Counter torque card (CTQ card) Azimuth test output (ground - red). Connect the open end of wire to the pin No 1 and 3 of analog input of NI daq card.
3. Connect open wire end of parallel shielded cable to pin #4 and #6 of analog input NI daq card and probe end to the Tacho HI terminals (ground - black) of Azimuth amplifier A and monitor card.
4. Switch off the rack power. Remove the FRC connector of the AIO card of SSC bin and connect the FRC connector end of the grounding cable to this. Connect the other end of the grounding cable to a suitable grounding point.
5. Switch on the rack power. Switch on Spectron multi output power supply and set it to 0.2 V. Then switch it off.
6. Connect the HHT to the D type connector (D2) of the SSC bin.
7. Switch the antenna to LOCAL mode.
8. Give a HOLD command to the antenna from the HHT as H, A

9. Make the Labview settings as follows:

9.1. Open lab view → New Project → Add step → Acquire Signal → Daqmx acquire → Analog input → Voltage. This will open Supported physical channel window with Dev (USB 6221) data channels.

9.2. Select ai0 → the OK. This will open Configuration window. Select Terminal configuration as RSE (Reversible single ended).

9.3. Recheck NI daq card connections using Connection diagram.

9.4. Select Step setup → Select Channel settings → Select Add channels or click + → Voltage → select ai1 → Click OK → Select Terminal configuration as RSE.

9.5. Press Record → Select Select all to record both input and output and name the log appropriately and press OK. Switch on the Spectron multi output power supply.

9.6. Go to Data view → Right click and select Add signals

→ Select all signals.
      Record for appropriate duration. Then, select Export to → Excel sheet. This will open MS excel sheet with the data values. Save the .xls file accordingly.
   This file can be later used to analyze the data.
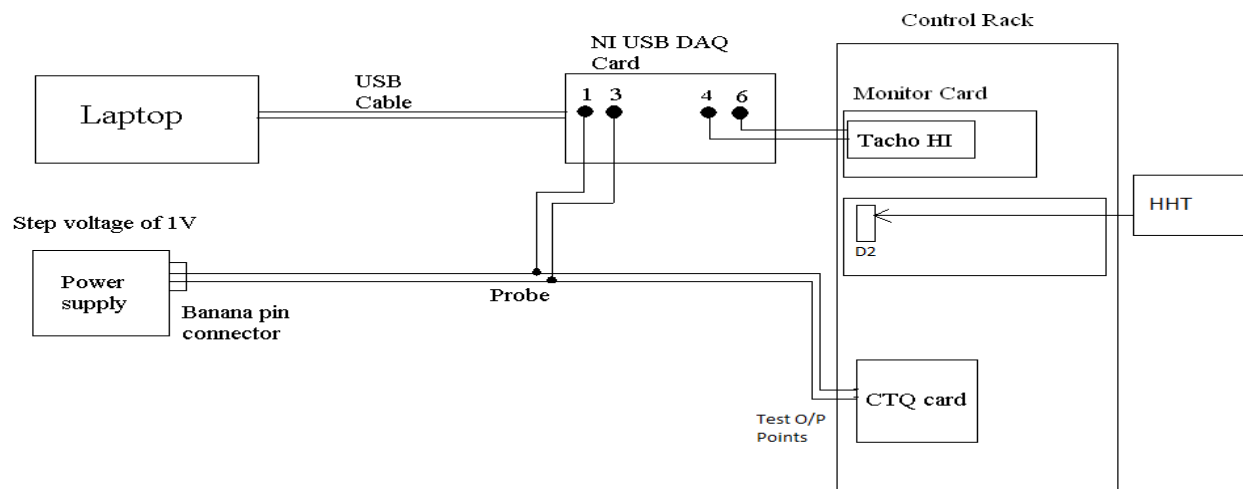
Figure4: Block diagram of step response test setup in velocity loop

3.4 <u>Step response test for position loop</u>

Scope of test:

Test is done to understand transient characteristics of antenna system for different step input signals

Procedure:

1. Test is done by giving 1 degree and 10 degree position step from control room.
2. Data file obtained from control room is used to plot step response in GNUPLOT.
3. Transient response parameters are calculated and tabulated as follows,

Table4: Step response test results

Parameters obtained from step response				
Sr no	Description	Abbreviation	Actual	Expected
1	Peak overshoot(%)	Mp		
2	Peak time	Tp		
3	Settling time	Ts		

3.5 Tracking test

Scope of test:

Test is done to check whether Antenna tracking before and after BLDC installation is same or not.

Procedure:
1. Track command is given from control room for different tracking speeds,
    Azimuth: 15 arcmin/min and 150 arcmin/min
    Elevation: 5 arcmin/min and 15 arcmin/min
2. Date logged by control room is plotted using GNUPLOT.
3. Tracking error is plotted as error = target position – Actual position

4. System Installation

4.1 <u>Brief description of system</u>

GMRT antenna is rotated on two axes: Azimuth and Elevation. Two motors in anti-backlash arrangement are used to drive each axis. At present Brushed motors are being used. As a part of upgrade it is being replaced by Brushless Motors. The mechanical arrangement has no changes. Also, the control system structure of three nested loops i.e. dual current loop within speed loop with backlash compensation within position loop is also maintained.

The Brushless motors (BLDC) are ac synchronous motors of Kollmorgen make. The drives (amplifiers) used to generate the motion of the motors are ServoStar712 (SS712).These are also of Kollmorgen make. The current or torque loop is implemented in the amplifiers. The speed loop is implemented in Programmable Multi-Axis Backlash controller (PMAC) from Delta Tau. The backlash compensation is also included in the program (PLC) which configures the dual motor speed loop. The PMAC acts as a very sophisticated counter torque card. The PMAC receives the position error from Servo computer and generates torque command for SS712 which generates switching commands for rotation of motors.

The BLDC rack houses the PMAC and the set of SS712, choke and ballast resistor for each motor. Hence we have a single rack for both azimuth and elevation. The rack is specially designed to meet the RFI/EMI requirements of GMRT. The cables connecting the BLDC motors are laid to meet the RFI/EMI requirements.

Following Figure5 shows how 3 nested loops are incorporated within new BLDC system. Figure6 shows a block diagram of how BLDC system replaces Brushed PMDC system in Antenna base.
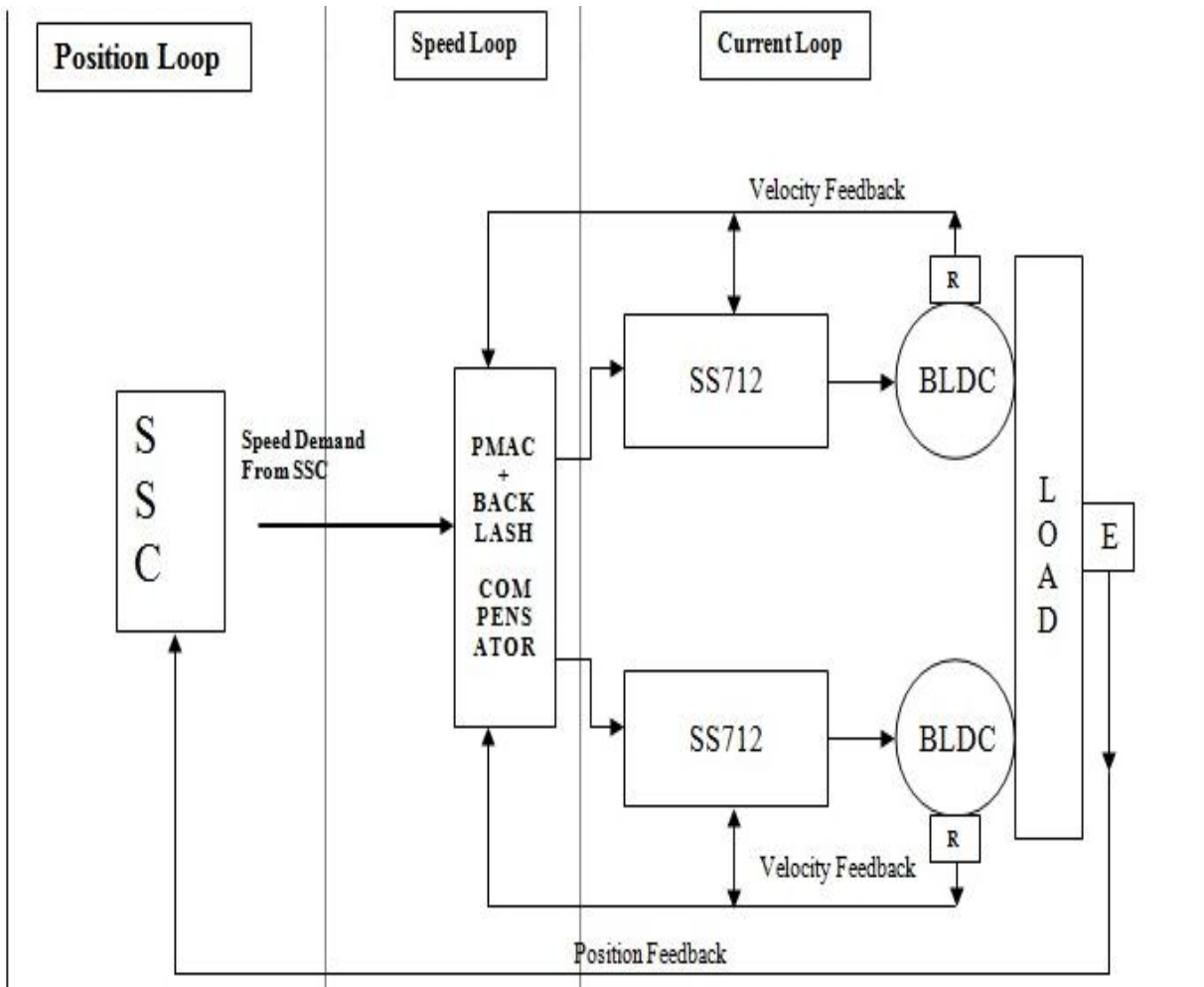
Figure5: Servo system block diagram with new BLDC system
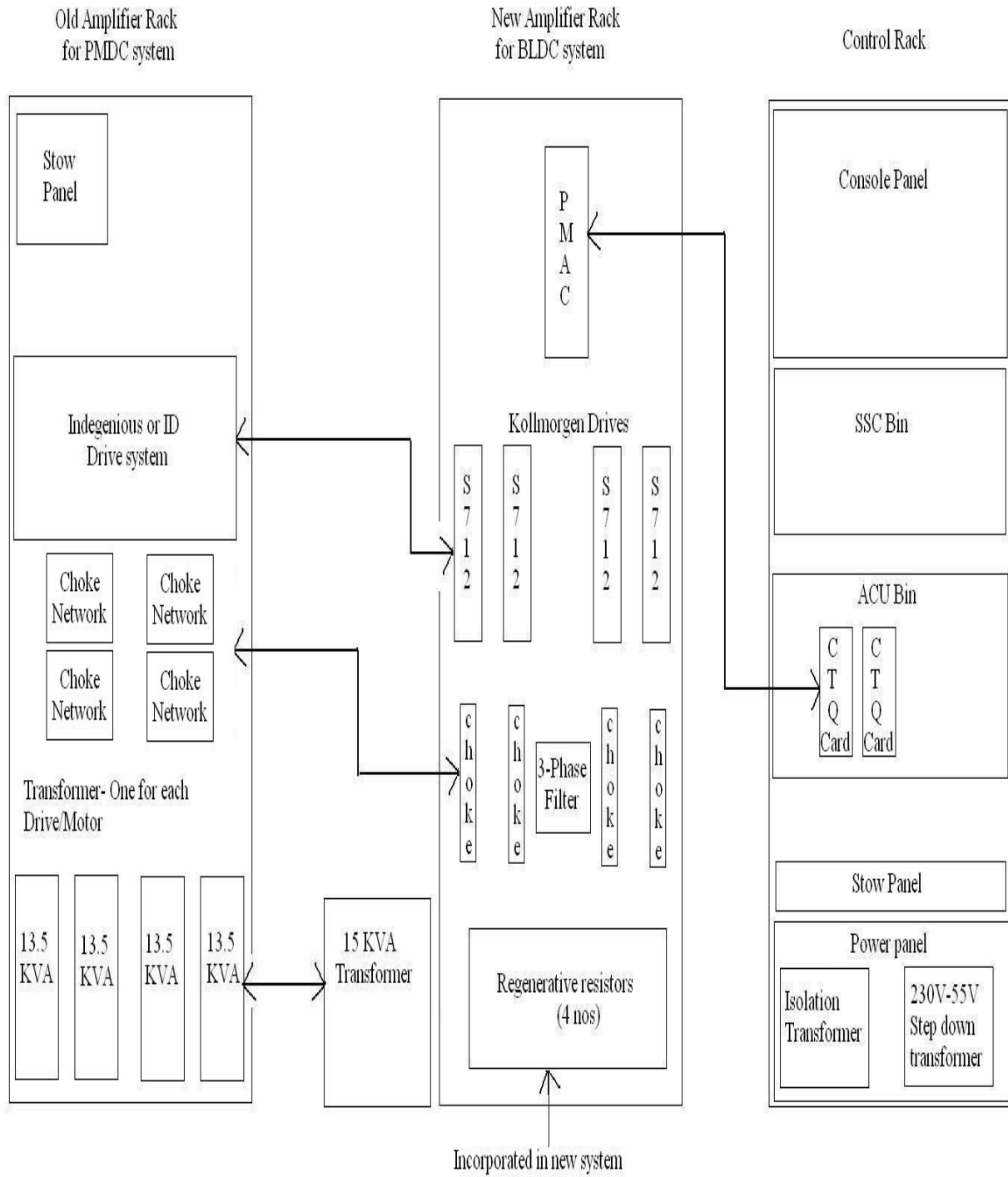
Figure6: PMDC system being replaced by BLDC system in Antenna base

4.2 Assembly of BLDC rack in laboratory

In upgrade phase first Antenna to commission BLDC system was Antenna C04. BLDC rack for this antenna was commissioned by M/s Maccon, GMBH at Germany. For subsequent antennas BLDC system is assembled at GMRT, Khodad site. Required electronics, cables, EMI/EMC compliant rack is procured and assembly is done by our team at GMRT.

Process involved in assembly of BLDC system rack is as follows,

1. Preparing cables for internal wiring of EMC cabinet

2. Wiring and Cables for EMC Cabinet

Pto..

4.2.1: Cable assemblies for EMC Cabinet (Internal rack wiring)

Table5: Details of cable assemblies for EMC cabinet

Name of the signal	Qty of cables	Specifications of Cable	Length (inches)	Refer section mentioned for connection details
3 phase AC power connector on rack rear plate to line filter	1	5 core shielded cable Size: 2.5 sq.mm	25	Section 4.2.2 A
Motor power +Brake Motor connector (Cabinet rear plate) to Choke	4	Lapp cable: 4G2.5 – 2x1	35	Section 4.2.2 E
Motor power +Brake Choke to Drive (SS712)	4	Lapp cable: 4G2.5 – 2x1	20	Section 4.2.2 E
Motor Resolver Drive to Resolver connector (Cabinet)	4	Lapp Cable: 4x2x0.25	97	Section 4.2.2 D
Load Encoder - Azimuth axis PMAC ENC connector to Encoder connector (Cabinet)	1	Lapp Cable: 8x2x0.25	100	Not connected (Encoder feedback is given to PC104)
Load Encoder- Elevation axis PMAC ENC connector to Encoder connector (Cabinet)- Elevation	1	Lapp Cable: 8x2x0.25	100	Not connected (Encoder feedback is given to PC104)

3 Ph AC power From MCB to RYB(3 phase supply) of Drive	4	3 Colours: Red, Yellow & Blue Size: 1.5 sq.mm	Azimuth 40 Elevation34	-
1 Ph Power-Fan From Line filter to 230V connector (Cabinet) (For Fan)	1	2 colours: Red and Black Size: 1.5 sq.mm each	43	-
DC Power Drive to 24V supply connector on rack rear plate	4	2 colours: Red and Black Size: 1.5 sq.mm each	54	Section 4.2.2 B Connector used: BEGA127MR23000006000
DC link Drive to regen resistor	4	3 colours: Red Blue & yellow Size: 1.5 sq.mm each	Azimuth 75 Elevation105	Section 4.2.2 C
Total cables	**47**			

4.2.2   Wiring and cables for EMC Cabinet (By M/s Maccon)

Note: Details in this section are referred from [3]

Cabinet internal wiring

A. Power wiring

The mains supply connection via a switch / fuse combination (32A) is fed to connector X0 of the Servostar. In order to reduce EMC radiation the cable should be shielded

Table6: Power wiring connection details

Servostar input power connector (X0)	Filter	Connector on cabinet backplane BEGA127MR23000006000
L1	L1	2
L2	L2	1
L3	L3	5
N?	N	4
PE	PE	PE
Shield	Shield	-
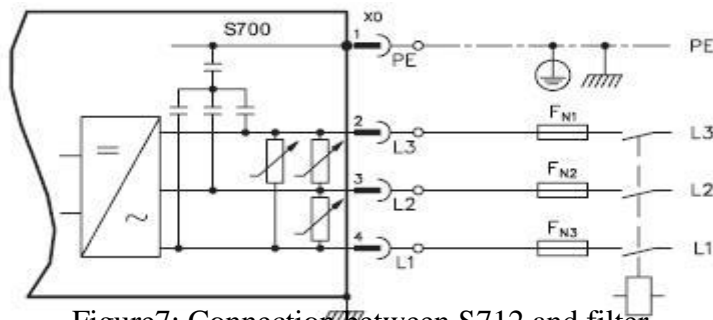
Figure7: Connection between S712 and filter

B. 24V auxillary supply

The 24V auxiliary (logic) supply connection from the 24V logic supply is fed to connector X4 of the S712. There is an internal filter in the Servostar in order to reduce EMC radiation. Refer Figure8 below for connection details.
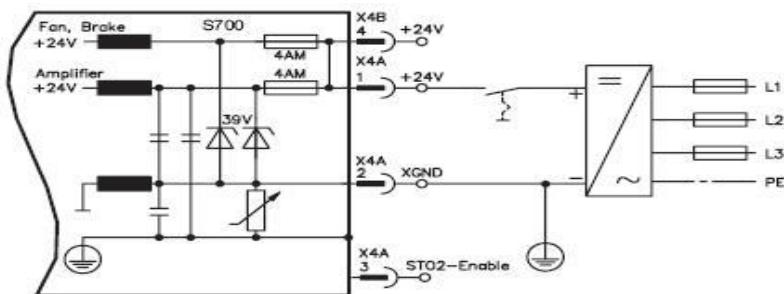
Figure8: 24V supply to S712

C. External brake resistor and DC bus link

In order to lower the regenerative loads to each Servostar the two drives belonging to one axis (so either Elevation or Azimuth) should have a connected DC bus link. Each individual drive has its own regeneration resistor (1500W with 33Ohm). Refer Figure9 below for connection details
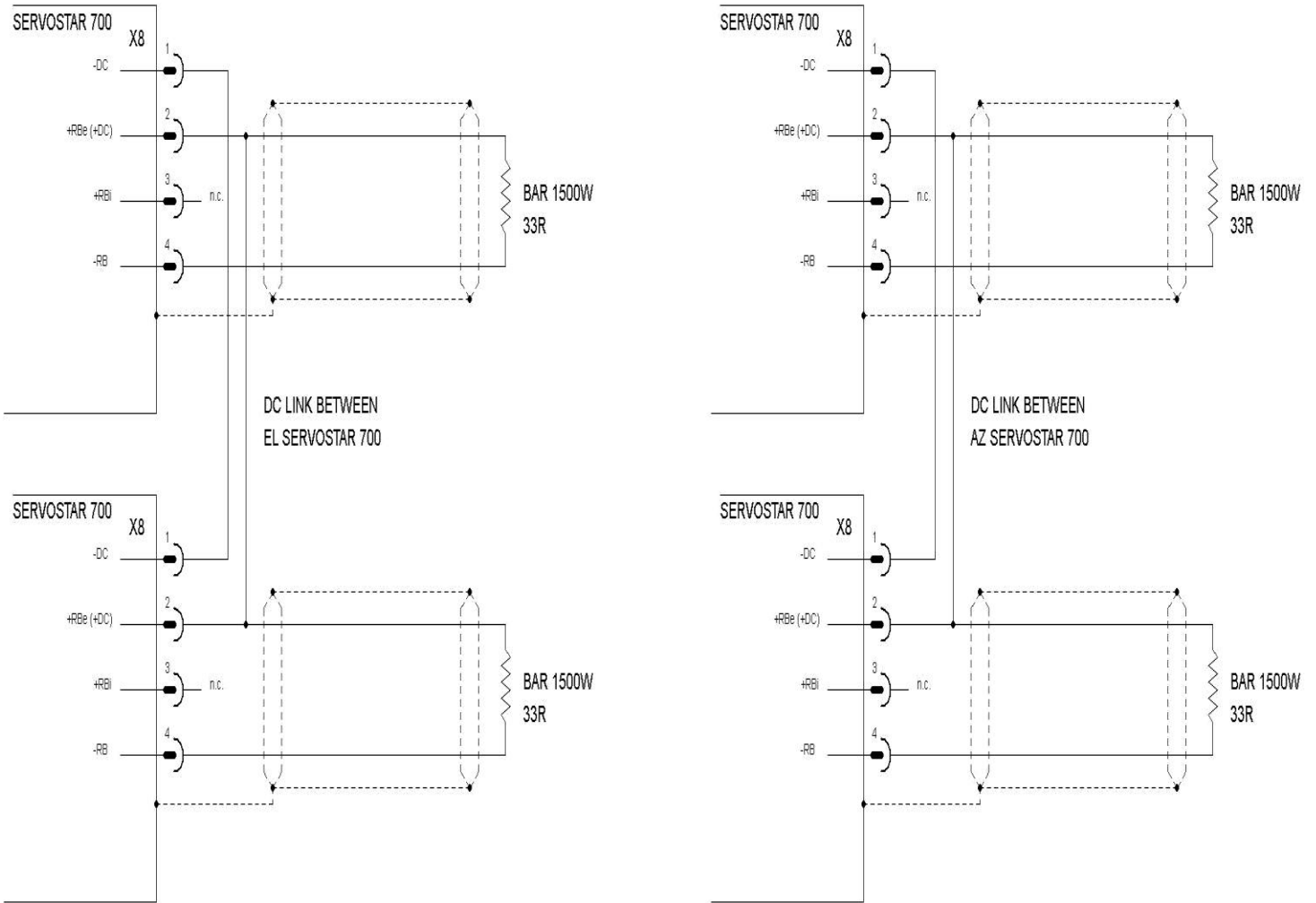
Figure9: Connection between S712 and external brake resistor

D. Resolver + thermal protection

The wiring has to be carried out for each of the 4 channels. Refer Figure10 for connection details

Table7: Resolver connection details

Servostar S712 Connector X0	AKM7 motor resolver connection	Connector on cabinet backplane ADFA021FR01000151000
2	Thermal protection 1(brown)	2
6	Thermal protection 2(White)	6
8	S1 Sine (grey)	8
4	S3 Sine (pink)	4
7	S2 Cosine (blue)	7
3	S4 Cosine (red)	3
9	R1 Reference (green)	9
5	R2 Reference (yellow)	5
Connector housing	Shield	Connector housing
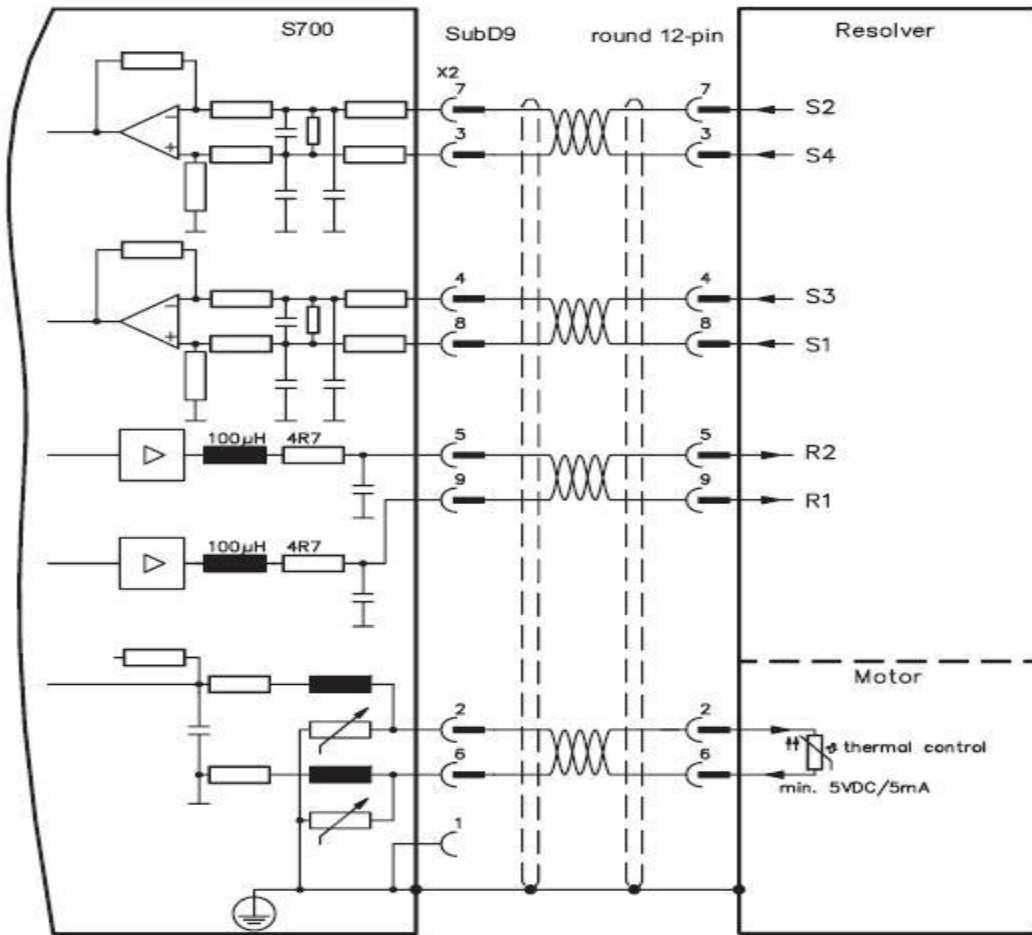
Figure10: Connection between S712 and motor resolver

E. Motor power and Brake
    The wiring has to be carried out for each of four channels. Refer figure11 for
    connection details.

Table8: Motor power and brake connection details

Servostar S712 Connector X9	AKM7 motor power connection	Connector on cabinet backplane BDFA108FR05000150000
4	Motor Phase U	1
5	Motor Phase V	4
6	Motor Phase W	3
3	Gnd	2
2	Brake +	A
1	Brake -	B
Connector housing	Shield	Connector housing
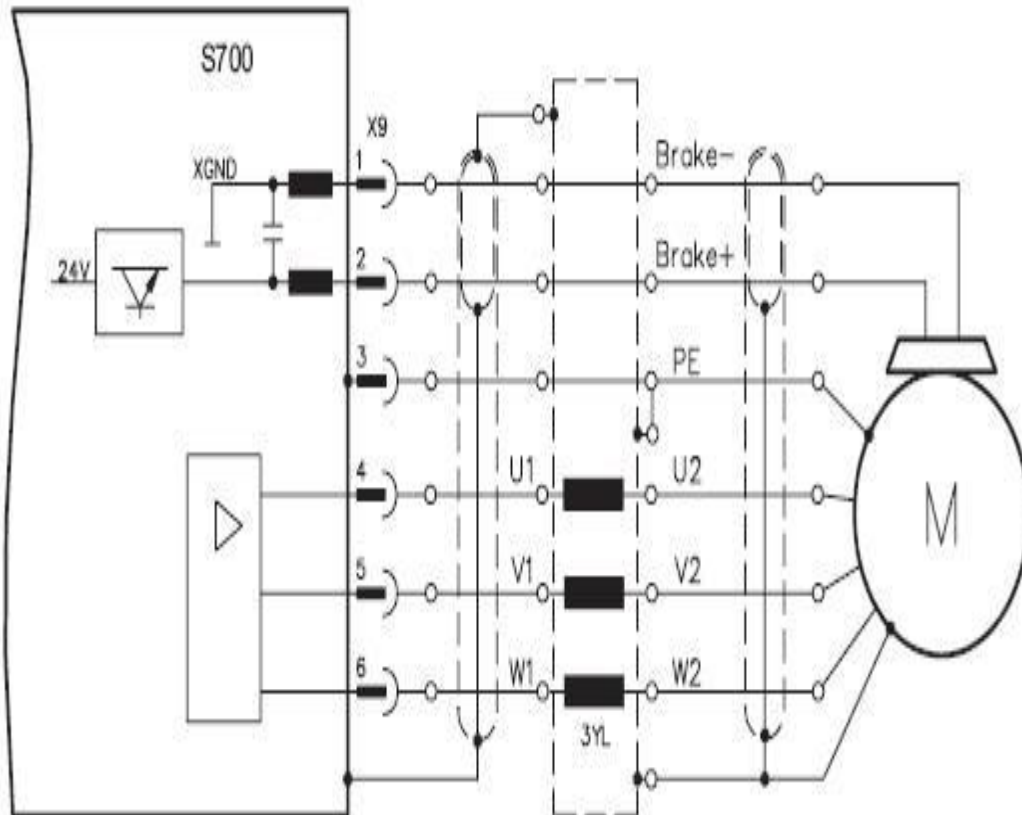
Figure11: Connection between S712 and motor power connector

F. Drive controller Interface

The interface between the drive Servostar S712 and the controller Turbo PMAC needs the following signal

1. Emulated resolver signal (Feedback signal from the motor to the controller)
2. Torque command signal from controller to drive (+/- 10V)
3. Drive enable signal from controller to drive
4. Drive status signal from controller to drive

Refer Figure12 below for details.
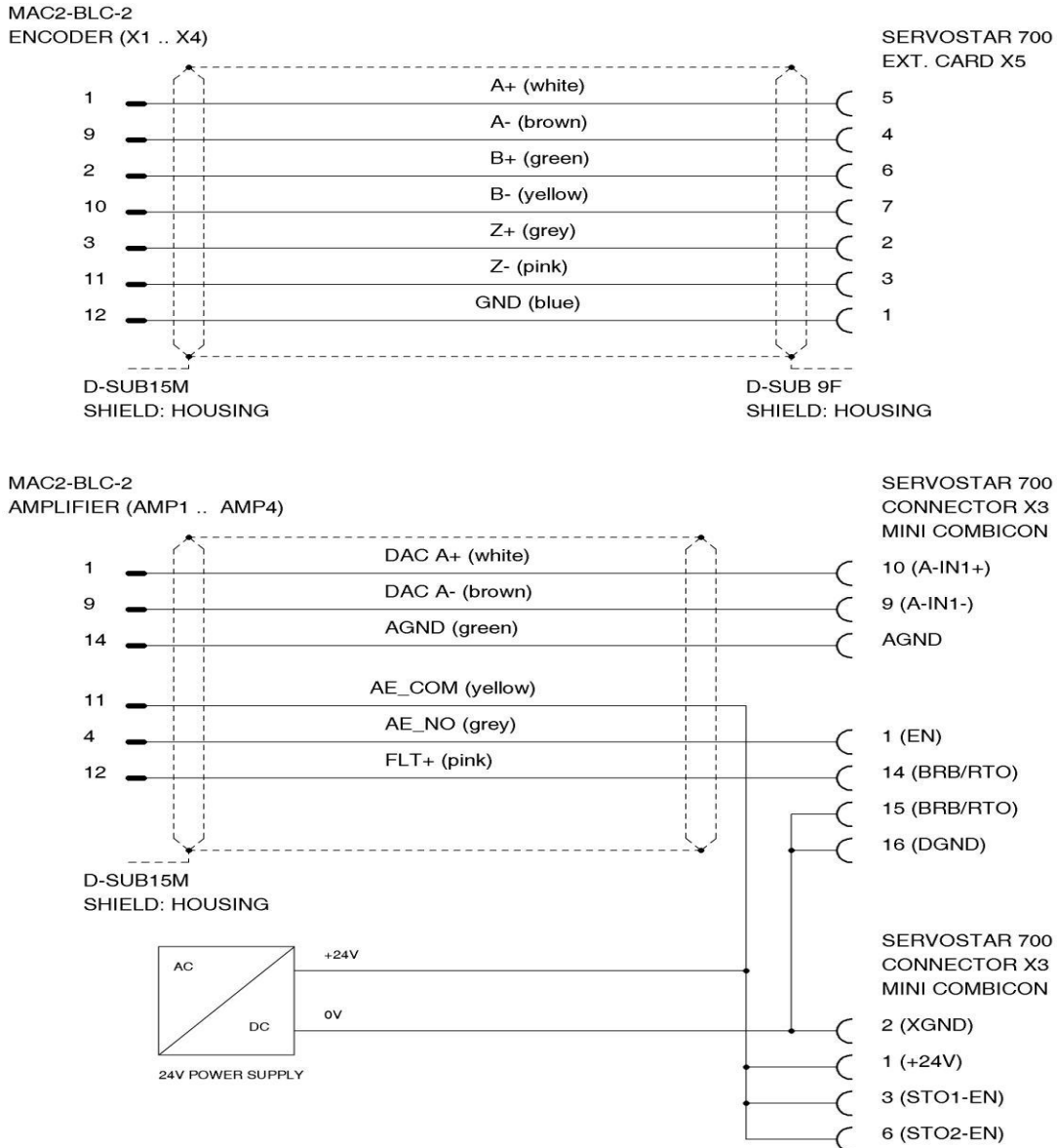
Figure12: Drive-controller Interface

4.2.3. Detailed circuit diagram of BLDC system rack

ENC 1 (X1)

1	Axis 'n' Encoders A +
2	B +
3	Index +
9	A -
10	B -
11	Index -
12	COMMON GND

AMP1

1	DAC1A +
4	AE_NO+ (Normally closed contact)
5	AFAULT -
9	DAC1A -
11	AE_COM
12	AFAULT +
14	AGND

→ Brake connection
→ EL (swap in wire at x31AB one drive) (1089)

white
Grey

pink ↑
green

(Red) (26 pin /12) RGS01 RGS02 (26 pin /13) (orange)

(STO-Enable3) X4A/3 ←

→ Drive up 24v from SS (26 pin/9)

X5

A +	5
B +	6
NI +	2
A -	4
B -	7
NI -	3
GND	1

X3A/B

(X3B) Analog IN1 +	10	white
(X3A) Enable	1	Red
(X3B) DGND	16	green
(X3B) Analog IN1 -	9	Brown
(X3B) BTB/RTO	14	Pink
(X3B) AGND	13	Green
(X3A) DIGITAL IN2/OUT1	6	Grey
(X3A) +24V -IO	8	yellow
(X3B) BTB/RTO	15	green

X4A/B

+24V X4A/1		Red
XGND X4A/2		blue
STO2-ENABLE X4A/3		yellow
+24V X4B/4		yellow
XGND X4B/5		green
STO1-ENABLE X4B/6		yellow

X4B/5

2-4V P.S

X3C

17		orange → A2 M1 Tacho (26 pin/4)
18		blue/white → A2 M1 current (26 pin/6)
19		green → Amplifier gnd (26 pin/3)

Figure13: Detailed circuit diagram of BLDC system rack

4.3 Modification in control rack

Modification is done in following cards to make Control rack (SSC and SSI bin) compatible with new BLDC rack.

1. Modification in AIO card:
   AIO card is modified to take care of speed and current scaling. Figure14 shows modification in card done.

2. Modification in Relay card:
   Relay card is modified to eliminate unwanted spurious voltage which gets introduced as input to speed loop. Figure15 shows modification in card done.

3. Modification in azimuth and elevation counter torque card:
   Counter torque card is modified to bypass circuitry which provides backlash compensation. In new BLDC system backlash compensation is done by Turbo PMAC controller. BLC algorithm is implemented as PLC software code.
   Figure16 and Figure17 show modification in card done.

4. Modification in power card/Brake card:
   Power card/Brake card houses circuitry for motors brake enable/disable supply voltage and stow panel supply voltage. New BLDC motors require 24V DC supply for enabling motors which is different from PMDC motors. To make brake enable supply voltage circuitry compatible to new system, power card/brake card is modified. Figure18 shows modification in card done.

5. Modification in control rack top
   Three phase contactor for BLDC rack is incorporated in power supply panel in control rack. Connectors for 3 phase supply in and 3phase supply out are incorporated on control rack top. Stow panel mounted on old Elevation rack is mounted in control rack. Connector for stow panel circuitry is also incorporated on control rack top.
   Figure19.1 shows modified control rack top. Table 19.1 shows details of each connector mentioned in Figure19.1

6. Modification in SSI PAL logic
   SSI bin has logic card which governs interlock logic for various signals. PAL IC U30 (For Azimuth) and U5 (For Elevation) are programmed with various Boolean equations for taking required logic decisions.
   In these equations minor modification is done for RGSO signal. Section20 gives details of changes done in equations.

1.
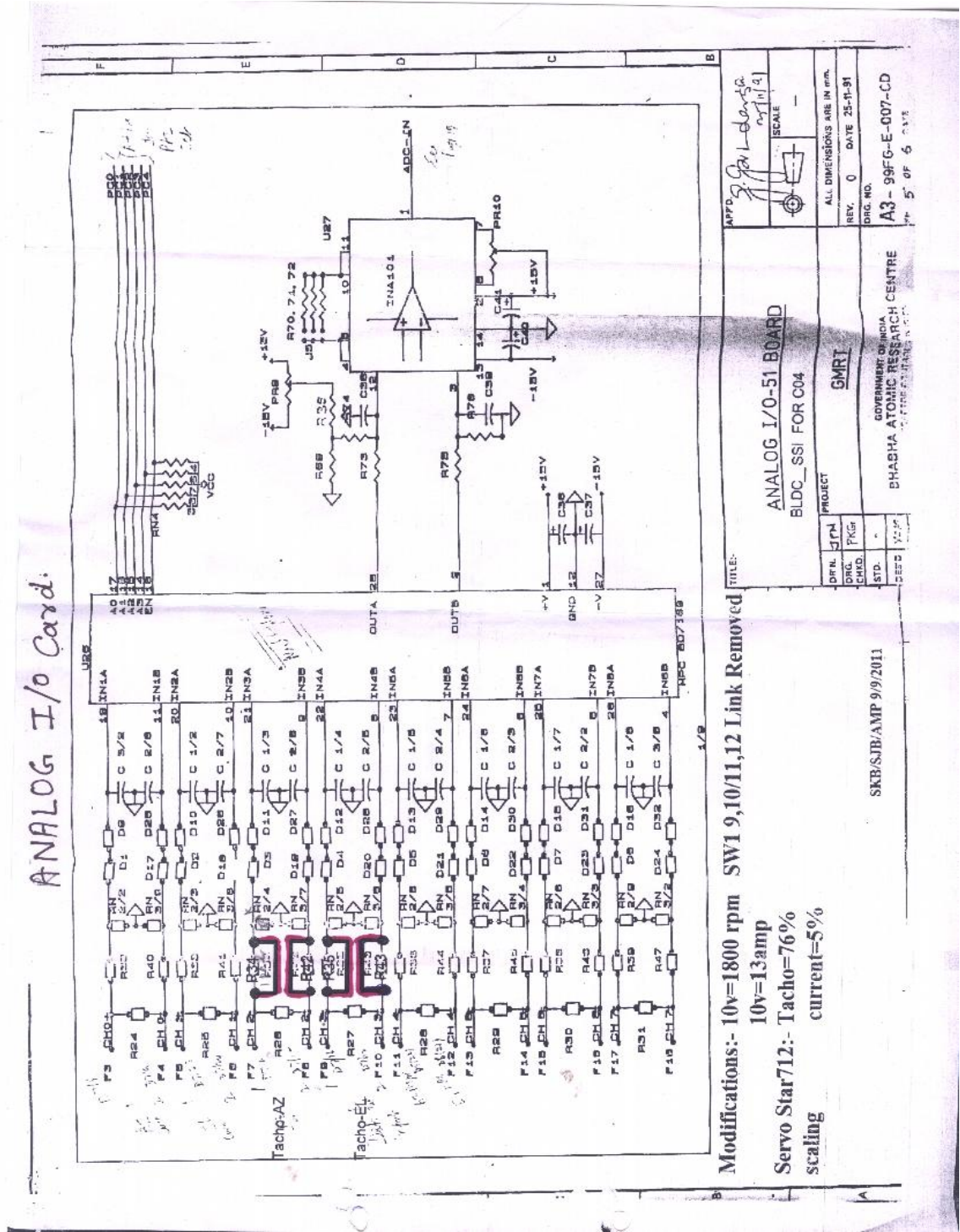
Figure14: Modification in AIO card

2.
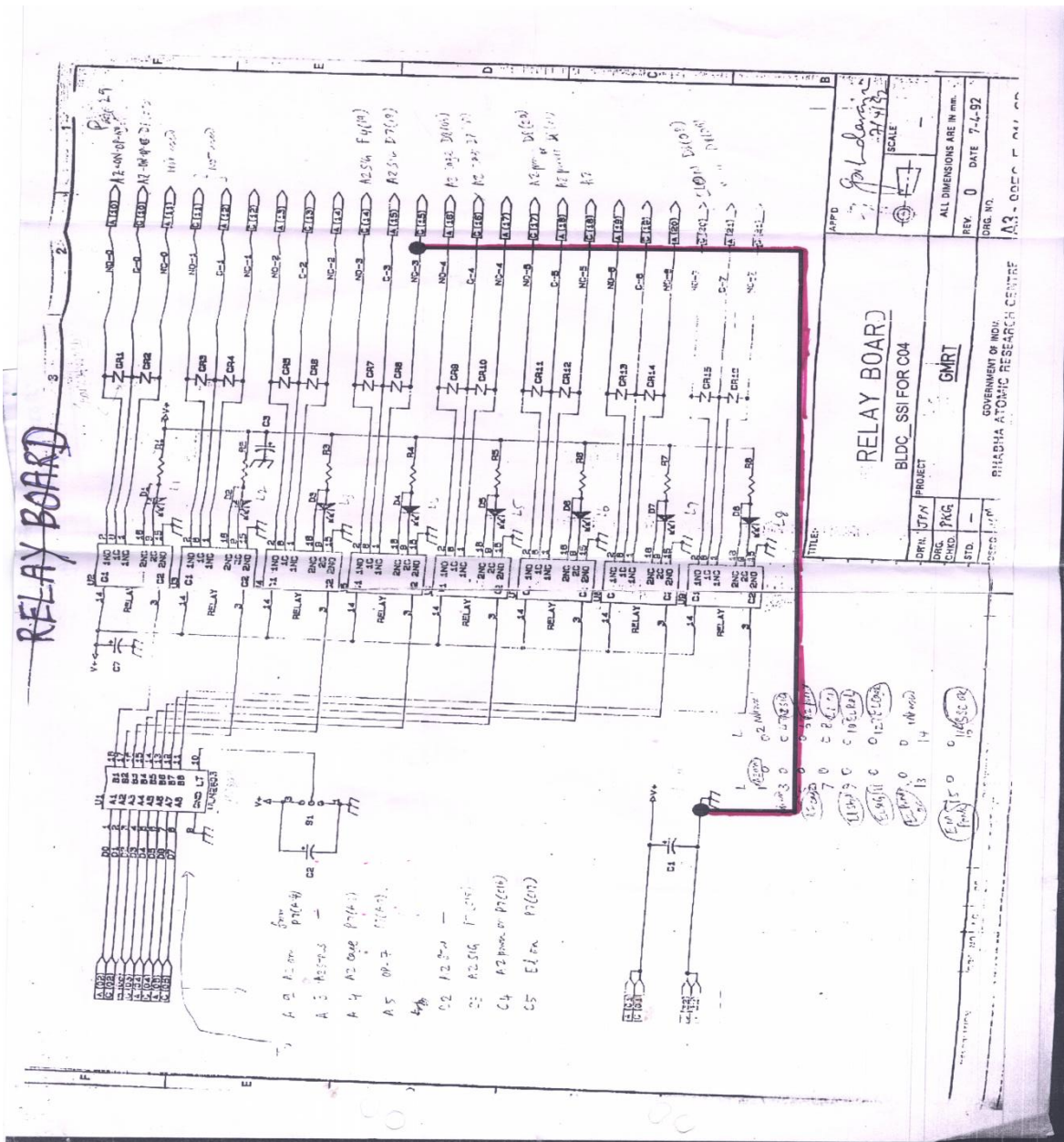
Figure15: Modification in Relay boar

3.
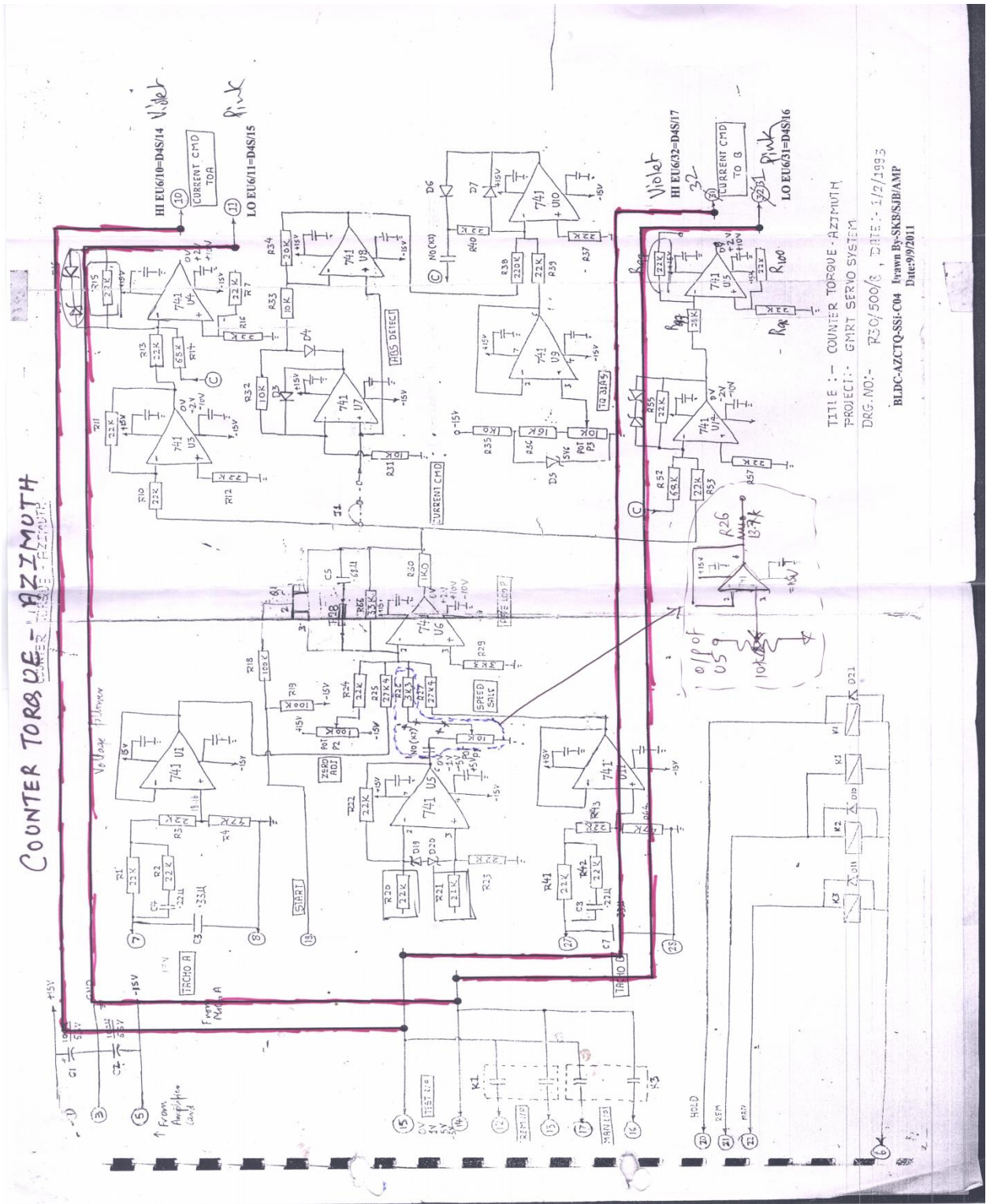
Figure16: Modification in Counter torque card (Azimuth axis)

4.
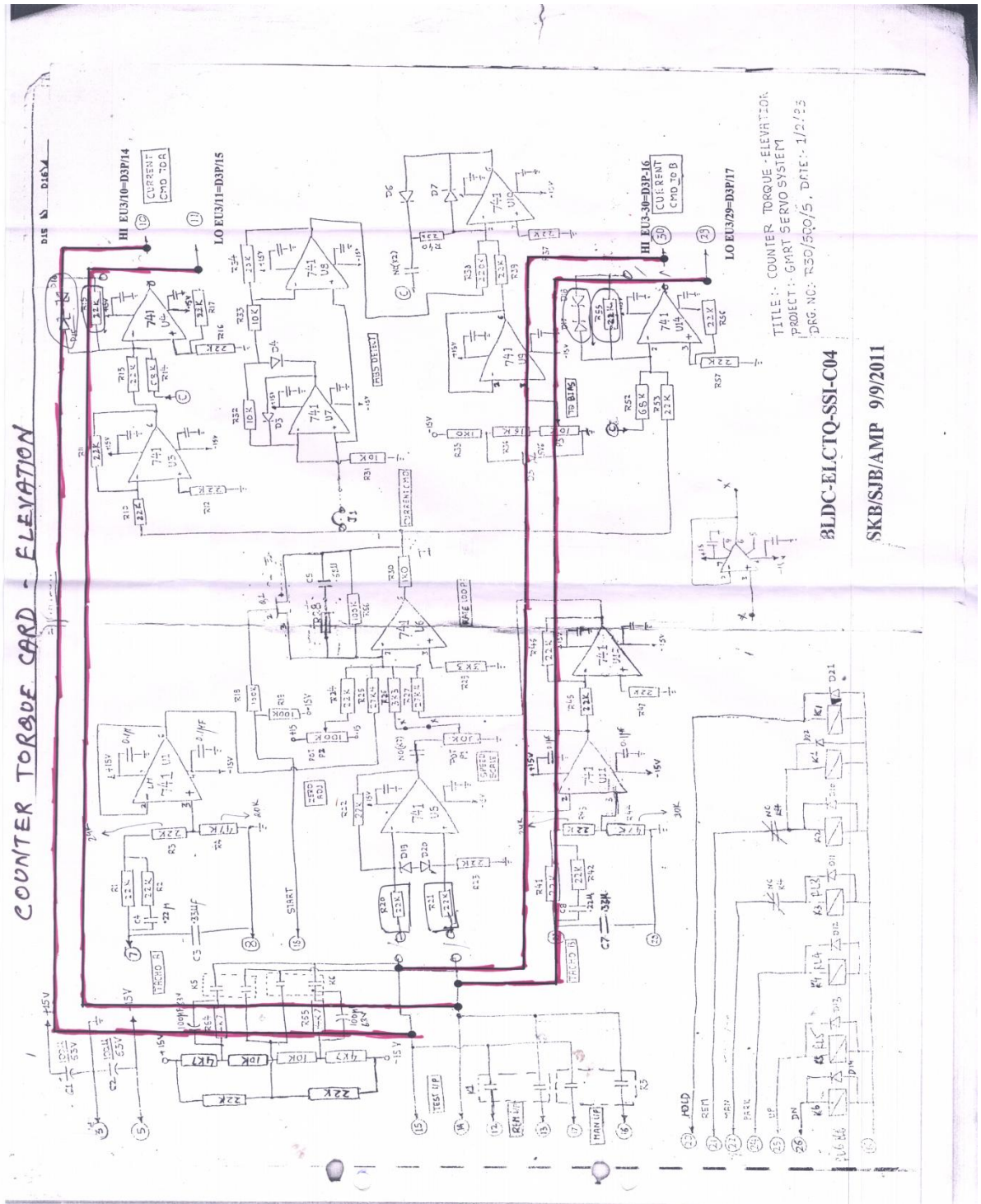
Figure17: Modification in counter torque card (Elevation)

5.
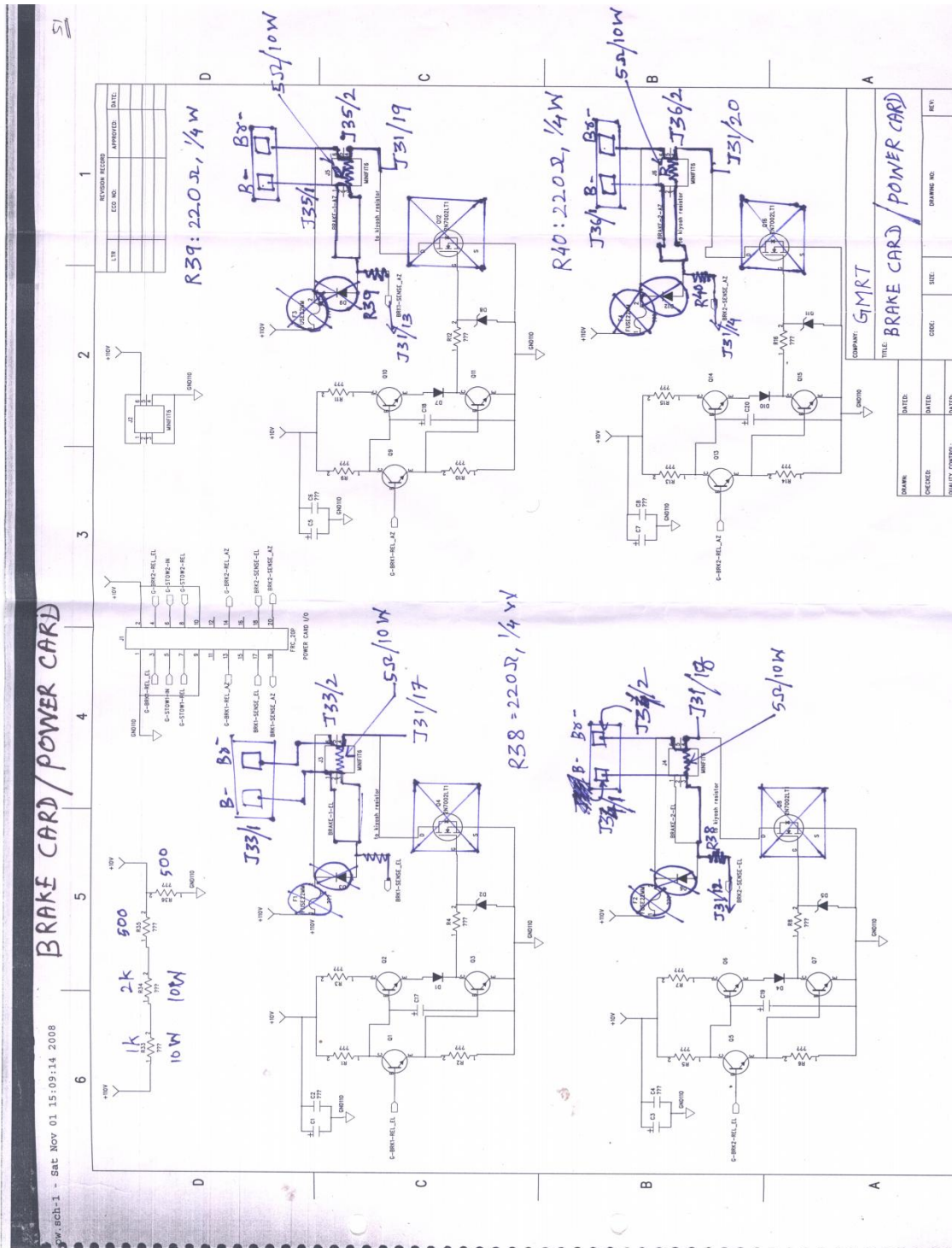
Figure18: Modification in Brake card/Power Card

34

6.
Control rack top
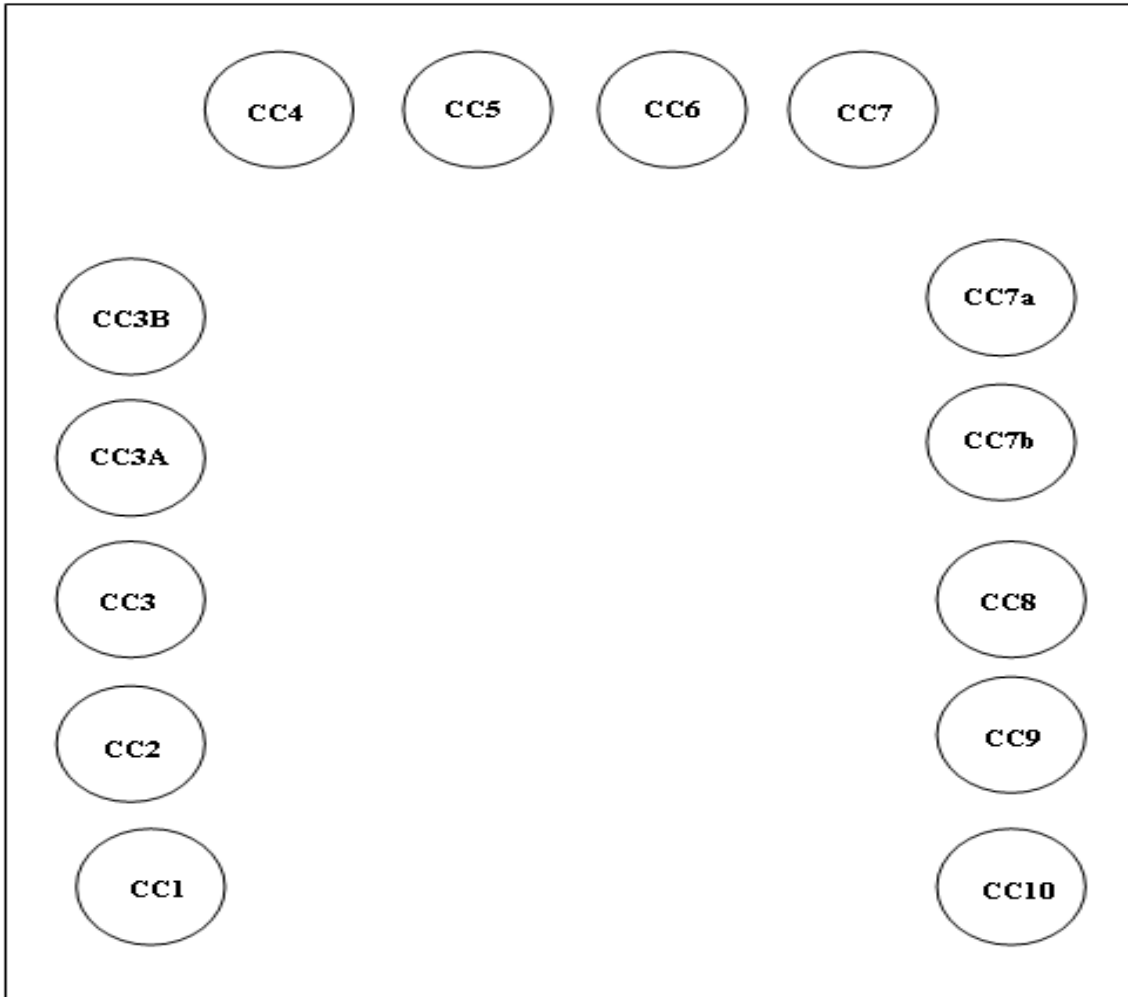
Figure 19: Modification in control rack top

Table9: Control rack top connector details

Connector number	Description of connector	Connector existing earlier or new one incorporated
CC1	37 pin connector for EL interlocks (amplifier) – MS3102R-28-215	Existing
CC2	37 pin connector for EL interlocks – MS3102R-28-215	Existing
CC3	22 pin connector for STOW Limit switch – MS3102R-28-113	Existing
CC3A	37 pin connector for EL Limit switch – MS3102R-28-215	Existing
CC3B	4 pin connector for EL Stow motor – MS3102R-22-225	New
CC4	14 pin connector for EL Encoder – MS3102R-22-195	Existing
CC5	14 pin connector for AZ Encoder – MS3102R-22-195	Existing
CC6	14 pin connector for Wind meter – MS3102R-22-195	Existing
CC7	4 pin connector for 1¢ power supply – MS3102R-22-22P	Existing
CC7a	4 pin connector for 3¢ power supply out to BLDC – MS3102R-22-225	New
CC7b	4 pin connector for 3¢ power supply in from MCB to BLDC – MS3102R-22-225	New
CC8	37 pin connector for AZ Limit switch – MS3102R-28-215	Existing
CC9	37 pin connector for AZ interlocks – MS3102R-28-215	Existing
CC10	37 pin connector for AZ interlocks – MS3102R-28-215	Existing

7. Modification in SSI PAL logic

Section20: Modification in SSI PAL logic

SSI U5 BLDC Logic IC modification
; PALASM Design Description
; U5
; -------------------------------- Declaration Segment ------------
TITLE   EL stop and axis control logic
PATTERN 1
AUTHOR   Shailendra K.Bagde
DATE   10/03/11
CHIP _U5bldc PAL16L8
; -------------------------------- PIN Declarations ---------------
PIN 2   BRK_SENSE_EL   COMBINATORIAL; INPUT
PIN 3   DRIVE_UP_EL   COMBINATORIAL; INPUT
PIN 4   EL_STOP_MAN   COMBINATORIAL; INPUT
PIN 5   EL_STOP_REM   COMBINATORIAL; INPUT
PIN 6   EL_STOP_PRKNG   COMBINATORIAL; INPUT
PIN 7   MAN   COMBINATORIAL; INPUT
PIN 8   REM   COMBINATORIAL; INPUT
PIN 9   AOVL_EL   COMBINATORIAL; INPUT
PIN 10   GND   ; INPUT
PIN 11   AXIS_ON_CMD_IP   COMBINATORIAL; INPUT
PIN 12   CAGE_EL   COMBINATORIAL; OUTPUT
PIN 14   RUN_EL_SSC   COMBINATORIAL; OUTPUT
PIN 15   STOP_EL_LAMP   COMBINATORIAL; OUTPUT
PIN 16   AXIS_ON_CMD_OP   COMBINATORIAL; OUTPUT
PIN 17   BRK_REL_OP   COMBINATORIAL; OUTPUT
PIN 18   CAGE_IOK_FAIL   COMBINATORIAL; OUTPUT
PIN 19   RGSO_EL_IP   COMBINATORIAL; OUTPUT
PIN 20   VCC   ; INPUT
; -------------------------------- Boolean Equation Segment ------
EQUATIONS
CAGE_EL= (DRIVE_UP_EL + /BRK_SENSE_EL + /(BRK_SENSE_EL + (/BRK_REL_OP))) +
MAN * (EL_STOP_MAN + EL_STOP_PRKNG) + REM * (EL_STOP_REM + EL_STOP_PRKNG)
+ CAGE_IOK_FAIL * (MAN + REM)
RGSO_EL_IP= (/BRK_REL_OP) * (MAN * /REM + REM * /MAN)
RUN_EL_SSC=DRIVE_UP_EL
STOP_EL_LAMP=/((MAN * EL_STOP_MAN) + (REM * EL_STOP_REM) + CAGE_IOK_FAIL
+ EL_STOP_PRKNG * (MAN + REM))
AXIS_ON_CMD_OP= AXIS_ON_CMD_IP + AOVL_EL
; -------------------------------- Simulation Segment ------------
SIMULATION
;---

SSI U30 - BLDC Logic IC modification

; PALASM Design Description
; -------------------------------- Declaration Segment ------------
TITLE   AZ STOP LOGIC

CHIP _U30 PAL16L8
; -------------------------------- PIN Declarations --------------
PIN 1	BRK1_SENSE	COMBINATORIAL; INPUT
PIN 2	BRK2_SENSE	COMBINATORIAL; INPUT
PIN 3	DRIVE1_UP	COMBINATORIAL; INPUT
PIN 4	DRIVE2_UP	COMBINATORIAL; INPUT
PIN 5	AZ_STOP_MAN	COMBINATORIAL; INPUT
PIN 6	AZ_STOP_REM	COMBINATORIAL; INPUT
PIN 7	MAN	COMBINATORIAL; INPUT
PIN 8	REM	COMBINATORIAL; INPUT
PIN 9	BRK_REL_OP	COMBINATORIAL; INPUT
PIN 10	GND	; INPUT
PIN 11	CAGE_IOKFAIL_OP	COMBINATORIAL; INPUT
PIN 12	AXIS_ON_CMD_OP	COMBINATORIAL; OUTPUT
PIN 13	AZ_BRKD	COMBINATORIAL; OUTPUT
PIN 14	RGSO_AZ_IP	COMBINATORIAL; OUTPUT
PIN 15	AZ_BRKD_SSC	COMBINATORIAL; OUTPUT
PIN 16	RUN_AZ	COMBINATORIAL; OUTPUT
PIN 17	STOP_AZ_LAMP	COMBINATORIAL; OUTPUT
PIN 18	DRIVE_UP	COMBINATORIAL; OUTPUT
PIN 19	CAGE_AZ	COMBINATORIAL; OUTPUT
PIN 20	VCC	; INPUT

; -------------------------------- Boolean Equation Segment ------
EQUATIONS
AZ_BRKD= / (BRK1_SENSE + BRK2_SENSE)
AZ_BRKD_SSC = (BRK1_SENSE + BRK2_SENSE)
DRIVE_UP = DRIVE1_UP + DRIVE2_UP
RUN_AZ = / (DRIVE1_UP + DRIVE2_UP)
CAGE_AZ = /RUN_AZ + /RGSO_AZ_IP + (/AZ_BRKD)
      + MAN * AZ_STOP_MAN + REM * AZ_STOP_REM
      + CAGE_IOKFAIL_OP * (MAN + REM)
RGSO_AZ_IP = /BRK_REL_OP * (MAN */REM + REM * /MAN)
STOP_AZ_LAMP = / ((MAN * AZ_STOP_MAN) + (REM * AZ_STOP_REM) +
(CAGE_IOKFAIL_OP *(MAN + REM)))
; -------------------------------- Simulation Segment ------------
SIMULATION

;---

4.4 BLDC-SSI interface

4.4.1 Block diagram of BLDC-SSI interface

Figure shows block diagram of BLDC-SSI interface. Details of connectors shown in Figure21 is given in section 4.4.2, table21
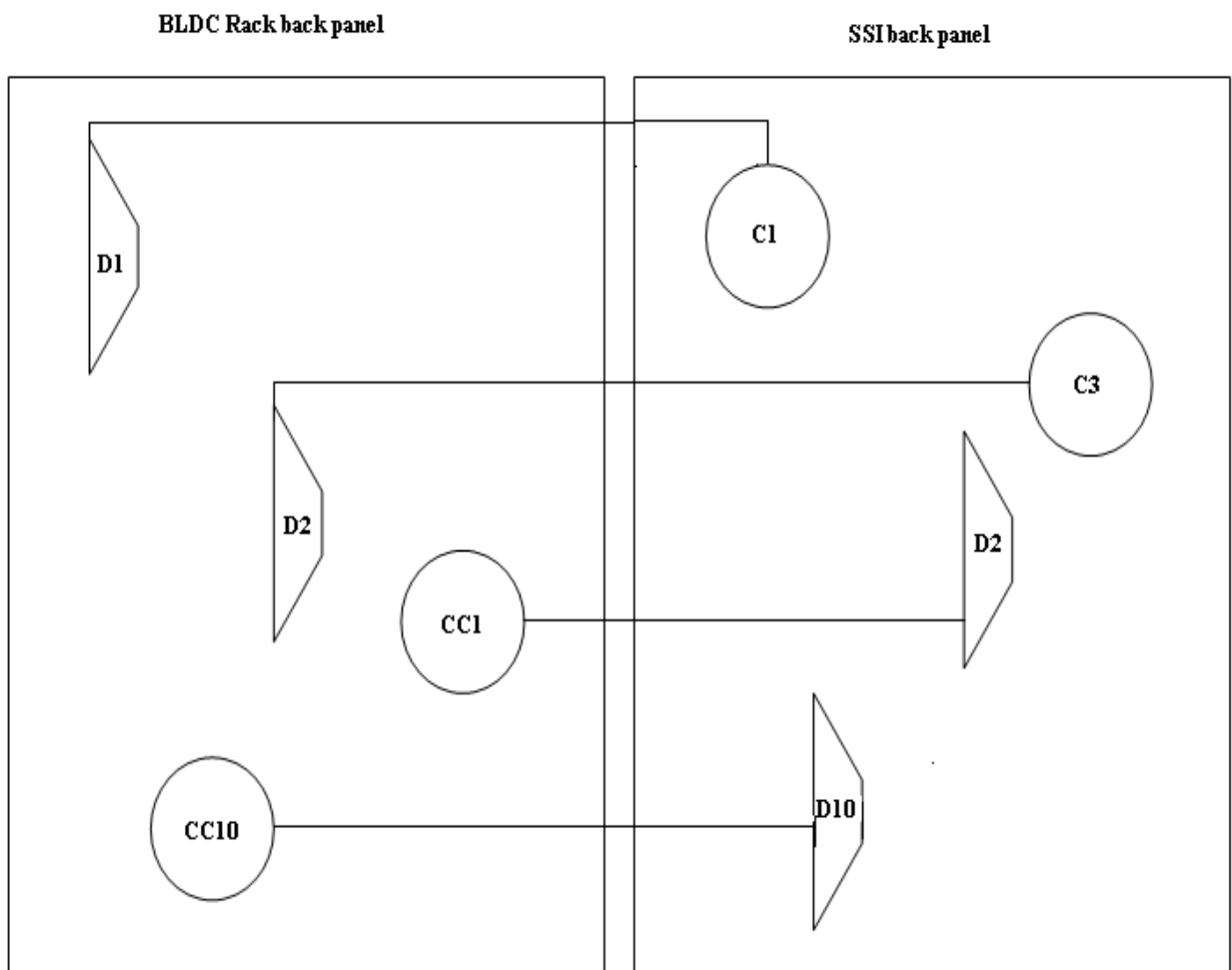
Figure21: Block diagram of BLDC-SSI interface

4.4.2 Connector details at both the ends

Table10: Connector details on BLDC back panel and SSI back panel

SSI Back panel	BLDC Rack back panel	Wire	Signal
Amphenol Round Shell connector **C3**-Socket: MS3102 R 18-12 S **C3**-Plug: MS3106 F 18-12 P	9 pin D type socket connector **D2**	0.75sq.mm 4 core braided copper wire	Azimuth brake signal
Amphenol Round Shell connector **C1**-Socket: MS3102 R 18-12 S **C1**-Plug: MS3106 F 18-12 P	9 pin D type socket connector **D1**	0.75sq.mm 4 core braided copper wire	Elevation brake signal
37 pin D type IDC crimp socket **D2**	Amphenol Round Shell connector **CC1-S**: MS3102R 28-21S	0.75sq.mm 37 core braided copper wire	SSI – BLDC Amplifier interface for Elevation
37 pin D type IDC crimp socket **D10**	Amphenol Round Shell connector **CC10-S**: MS3102R 28-21S	0.75sq.mm 37 core braided copper wire	SSI – BLDC Amplifier interface for Azimuth

4.4.3 BLDC rack and SSI bin interfacing (Brake signals interface connection details)

Figure22 shows connection schematic between BLCDC rack and control rack and Table 11 gives details in tabular form
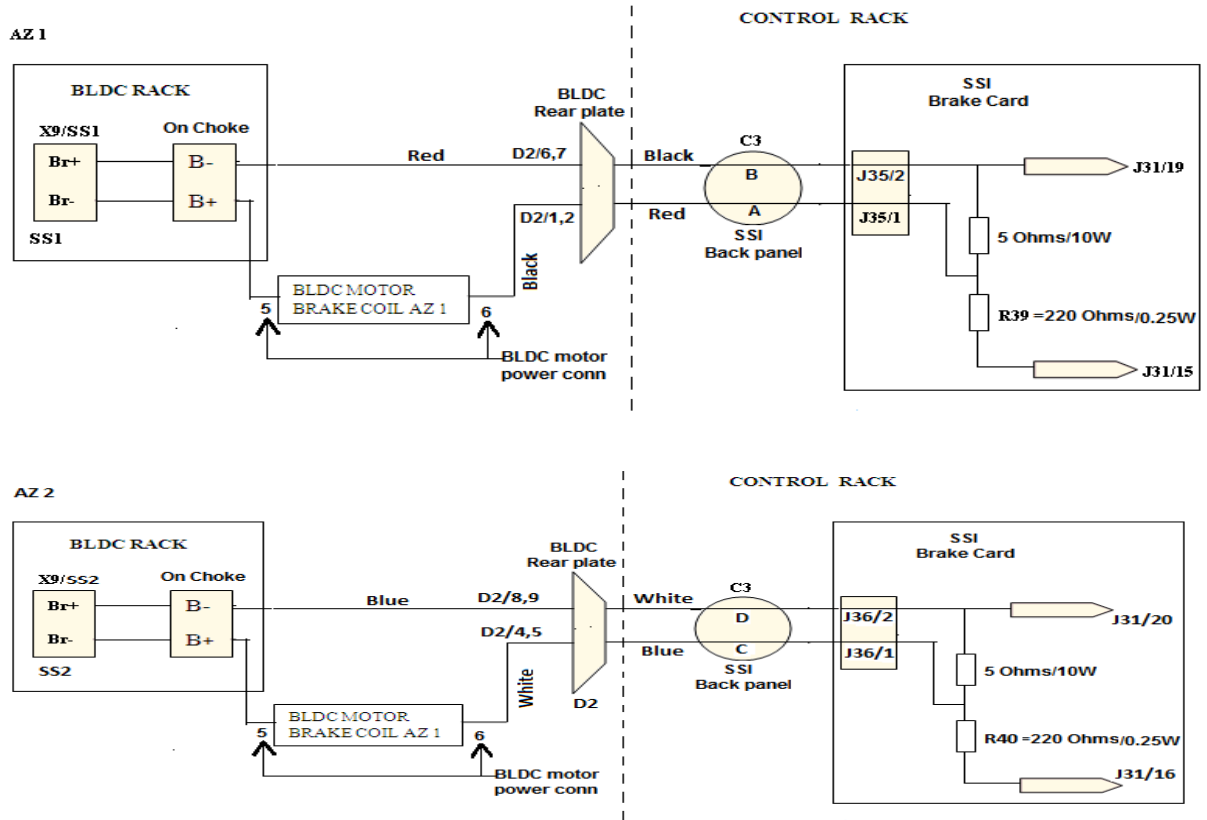
Figure22: Brake signal interface connection details (Azimuth axis)

Table11: Connections details in tabular form for Figure22

				Control rack top	D1 -Plug pin	D1 Recptcle Socket	BLDC SS712
	SSI C1			mount	BLDC D TYPE 9PIN	BLDC RACK MOUNT	To Choke
Sr.No		Signal	Color	Mating Connector	Terminnation end		Terminal for Sense
1	A	BR+	RED		1,2	1,2	X9/SS1-Br+
2	B	Br-	BLACK		6,7	6,7	X9/SS1-Br-
3	C	BR+	BLUE		4,5	4,5	X9/SS2-Br+
4	D	Br-	WHITE		8,9	8,9	X9/SS2-Br-

Figure23 shows connection schematic between BLCDC rack and control rack and Table 12 gives details in tabular form
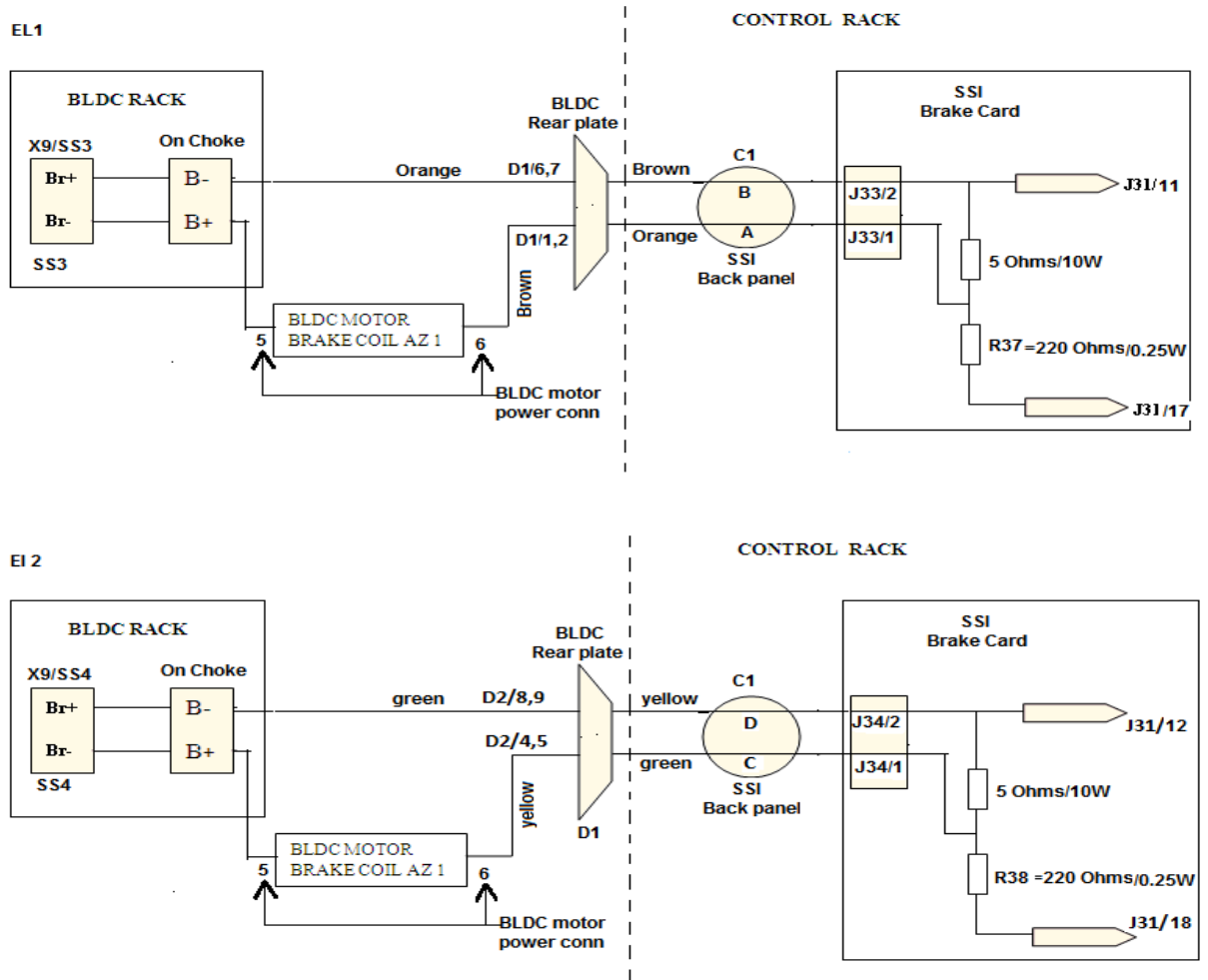
Figure23: Brake signal interface connection details (Elevation axis)

Table12: Connections details in tabular form for figure23

				BLDC EL BRAKE SENSE WIRING DETAILS			
				Control rack top	D2 -S\Plug Socket	D2-Recptcle Pin	BLDC SS712
	SSI C3			mount	BLDC D TYPE 9PIN	BLDC RACK MOUNT	To Choke
Sr.No		Signal	Color	Mating Connector	Terminnation end		Terminal for Sense
1	A	BR+	ORANGE		1,2	1,2	X9/SS3-Br+
2	B	Br-	BROWN		6,7	6,7	X9/SS3-Br-
3	C	BR+	YELLOW		4,5	4,5	X9/SS4-Br+
4	D	Br-	GREEN		8,9	8,9	X9/SS4-Br-

4.4.4 BLDC rack and SSI bin interfacing (Drive signals interface connection details)

Azimuth (D10-CC10 interfacing) Table13: BLDC-SSI interface Azimuth axis

SSI IDC	Control	BLDC 37 PIN CONNECTOR WIRING DETAILS FOR -AZ					BLDC REAR	BLDC RACK	Wire	INSIDE RCK	BLDC internal
D10/37PIN	Rack	SSI	Wire	SSI Connector	BLDC	Control	CA1-S	BLDC RACK	Length (mtr)	INSIDE RCK	26 pin
	CC10-P	SIGNAL	COLOR	Description	BLDC SIGNAL	Rack		BLDC Connector Details		COLOR	
1	A	HI	Black	0-10v to AMP	AZ Error +(High)		A	PMAC CH7 D9/2		PINK	1
2	B	LO	Brown	Amplifire A	AZ Error -(Low)		B	PMAC CH7 D9/6		Brown	2
3	C	GND	Red	Amplifire GND	Amplifire GND		C	SS1/X3C/18		BLUE/WHITE	3
4	D	0TO24V	Orange	Tacho HI	AZ Motor 1 Tacho		D	SS1/X3C/17		Orange	4
5	E	0V	Yellow	Tacho LO	GND		E	SS1/X3C/18		BLUE/WHITE	5
6	F	0TO2V	Green	Motor Current	AZ Motor 1 Current		F	SS1/X3C/19		Green	6
7	G	AGND	Blue	Common GND	Common GND		G	SS1/X3C/18		BLUE/WHITE	7
8	H	24V	Violet	TO Relay Amp			H	-		Violet	8
9	J	Drive UP	Grey	Drive UP-A	Drive UP 24V from SS		J	SS1/X3A/6		Grey	9
10	K	CAGE	White	Cage -A			K	-		White	
11	L	15V+	Black	Amplifire A			L	-		Black	10
12	M	15V-	Brown	Amplifire A			M	-		Brown	11
13	N	RGSO1	Red	Amplifire A	RGSO1		N	SS1/X3A/1		Red	12
14	P	RGSO2	Orange	Amplifire A	RGSO2		P	PMAC/AMP3/4		Orange	13
15	R	HI	Yellow	0-10V to Amp			R	-		PINK	
16	S	LO	Green	Amplifire B			S	-		Brown	
17	T	GND	Blue	Amplifire GND	Amplifire GND		T	SS2/X3C/18		BLUE/WHITE	14
18	U	0TO24V	Violet	Tacho HI	AZ Motor 2 Tacho		U	SS2/X3C/17		Orange	15
19	V	0V	Grey	Tacho LO	GND & control TDR	control TDR coil	V	SS2/X3C/18		BLUE/WHITE	16
20	W	0TO2V	White	Motor Current	AZ Motor 2 Current		W	SS2/X3C/19		Green	17
21	X	A GND	Black	Common GND	Common GND		X	SS2/X3C/18		BLUE/WHITE	18
22	Z	24V	Brown	24V			Z	-		Violet	19
23	a	24V	Red	Drive UP-B	Drive UP 24V from SS		a	SS2/X3A/6		Grey	20
24	b	CAGE	Orange	Cage-B			b	-		White	
25	c	15V+	Yellow	Amplifire B			c	-		Black	21
26	d	15V-	Green	Amplifire			d	-		Brown	22
27	e	RGSO1	Blue	Amplifire B	RGSO1		e	SS2/X3A/1		Red	23
28	f	RGSO2	Violet	Amplifire B	RGSO2		f	PMAC/AMP4/4		Orange	24
29	g	24V	Grey	AC OK	3ph TDR	3ph TDR coil	g	-		Grey	
30	h	AC OK EL	White	From Contactor	3ph TDR	3ph TDR coil	h	-		White	
31	j	AXIS ON	Black	TO TDR 24V	control rack TDR	control TDR coil	j	-		Black	
32	k	STOWING	Brown	From IN cont			k	-		Brown	
33	m	RLSG	Red	From REL cont			m	-		Red	25
34	n	AXIS ON	Orange	To TDR GND	XGND		n	SS1 & SS2 =X3B/16		YELLOW/WHITE	26
35	p						p	-			
36	r						r	-			
37	s						s	-			

PMAC	
SS712-AZ	
GND	

*Interfacing details formulated by Shri. SJB, servo

Elevation (D2-CC1 Interfacing) Table14: BLDC-SSI interface Elevation axis

Control	Old	BLDC 37 PIN CONNECTOR WIRING DETAILS FOR -EL				REAR PLATE			BLDC	
Rack	SSI	Wire	SSI Connector	BLDC	control	BLDC	INSIDE RACK	Internal	INSIDE RACK	Internal
CC1-P	SIGNAL	COLOR	Description	BLDC SIGNAL	rack	CE12-S	BLDC Connector Details	Length(mtr)	BLDC COLOR	26 pin
A	HI	Black	0-10v to AMP	EL Error +(High)		A	PMAC CH8 D9/2		PINK	1
B	LO	Brown	Amplifire A	EL Error -(Low)		B	PMAC CH8 D9/6		Brown	2
C	GND	Red	Amplifire GND	Amplifire GND		C	SS3/X3C/18		BLUE/WHITE	3
D	0TO24V	Orange	Tacho HI	EL Motor 1 Tacho		D	SS3/X3C/17		Orange	4
E	0V	Yellow	Tacho LO	GND		E	SS3/X3C/18		BLUE/WHITE	5
F	0TO2V	Green	Motor Current	EL Motor 1 Current		F	SS3/X3C/19		Green	6
G	AGND	Blue	Common GND	Common GND		G	SS3/X3C/18		BLUE/WHITE	7
H	24V	Violet	TO Relay Amp			H	-		Violet	8
J	Drive UP	Grey	Drive UP-A	Drive UP 24V from SS		J	SS3/X3A/6		Grey	9
K	CAGE	White	Cage -A			K	-		White	
L	15V+	Black	Amplifire A			L	-		Black	10
M	15V-	Brown	Amplifire A			M	-		Brown	11
N	RGSO1	Red	Amplifire A	RGSO1		N	SS3/X3A/1		Red	12
P	RGSO2	Orange	Amplifire A	d		P	PMAC/AMP3/4		Orange	13
R	HI	Yellow	0-10V to Amp			R	-		PINK	
S	LO	Green	Amplifire B			S	-		Brown	
T	GND	Blue	Amplifire GND	Amplifire GND		T	SS4/X3C/18		BLUE/WHITE	14
U	0TO24V	Violet	Tacho HI	EL Motor 2 Tacho		U	SS4/X3C/17		Orange	15
V	0V	Grey	Tacho LO	GND & control TDR		V	SS4/X3C/18		BLUE/WHITE	16
W	0TO2V	White	Motor Current	EL Motor 2 Current		W	SS4/X3C/19		Green	17
X	A GND	Black	Common GND	Common GND		X	SS4/X3C/18		BLUE/WHITE	18
Z	24V	Brown	24V			Z	-		Violet	19
a	24V	Red	Drive UP-B	Drive UP 24V from SS		a	SS4/X3A/6		Grey	20
b	CAGE	Orange	Cage-B			b	-		White	
c	15V+	Yellow	Amplifire B			c	-		Black	21
d	15V-	Green	Amplifire			d	-		Brown	22
e	RGSO1	Blue	Amplifire B	RGSO1		e	SS4/X3A/1		Red	23
f	RGSO2	Violet	Amplifire B	RGSO2		f	PMAC/AMP4/4		Orange	24
g	24V	Grey	AC OK	3ph TDR	3ph TDR coil	g	-		Grey	
h	AC OK EL	White	From Contactor	3ph TDR	3ph TDR coil	h	-		White	
j	AXIS ON	Black	TO TDR 24V			j	-		Black	
k	STOWING	Brown	From IN cont			k	-		Brown	
m	RLSG	Red	From REL cont			m	-		Red	25
n	AXIS ON	Orange	To TDR GND	XGND		n	SS3 & SS4 =X3B/16		YELLOW/WHITE	26
p						p	-			
r						r	-			
s						s	-			
									PMAC	
									SS712 -EL	
									GND	

*Interfacing details formulated by Shri. SJB, servo

<u>4.5 Modification in BLDC drive (Servostar S712)</u>

We get information about maximum speed at which motor is rotating and maximum current being drawn by motor from drive system. This information is given as an input to SSC which uses this data for over speed and over current indication

Output voltage from drives corresponding to maximum speed and maximum current value is different in BLDC system as compared to PMDC system. To scale down voltage level as per requirement of SSC, scaling is done in drive (servostar S712) using GUI as shown in Figure25.

Scaling factor values (in percentage) is obtained as follows,

1. SPEED SCALING:

For PMDC Drive:
Tacho constant: 17V = 1000rpm

For BLDC SS712 Drive:
Analog Output equivalent for speed   : 10V = 1800rpm
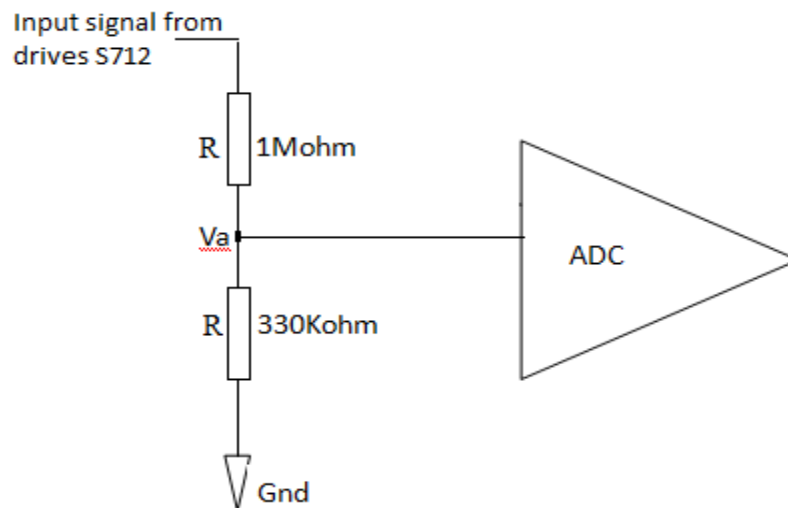
At the Analog Card the resistance divider is shown:

Figure24: AIO card modifications (For input signal scaling)

If PMDC Motor rotates at 2000rpm, voltage received at A/I O card is 34V
Then across the voltage divider,

Va = $34*[(330\text{x}10^3)/ (1\text{x}10^6 + 330\text{x}10^3)]$
   = 11220000 / 1330000
   = 8.4V

Thus for PMDC
 8.4V=2000rpm

Therefore for 10V =? (How much rpm)

rpm = 2000 x 10 / 8.4 = 2380 rpm

For BLDC the maximum voltage is 10V, hence the resistor 1Mohm is removed and Va is 10V for 1800rpm.This requires scaling at SS712 end. The scaling Factor (n1) is calculated as:

100% (10V) corresponds to 1800rpm then

 n1 = (100 x 1800) / 2380

 n1 = 75.63%   ; scaling percentage

2. CURRENT SCALING:

For PMDC:

10A = 250A

For BLDC:

10V=13A

Scaling factor (n2) for current
   n2 = 100 x 13/250
   n2 = 5%   ;Scaling percentage
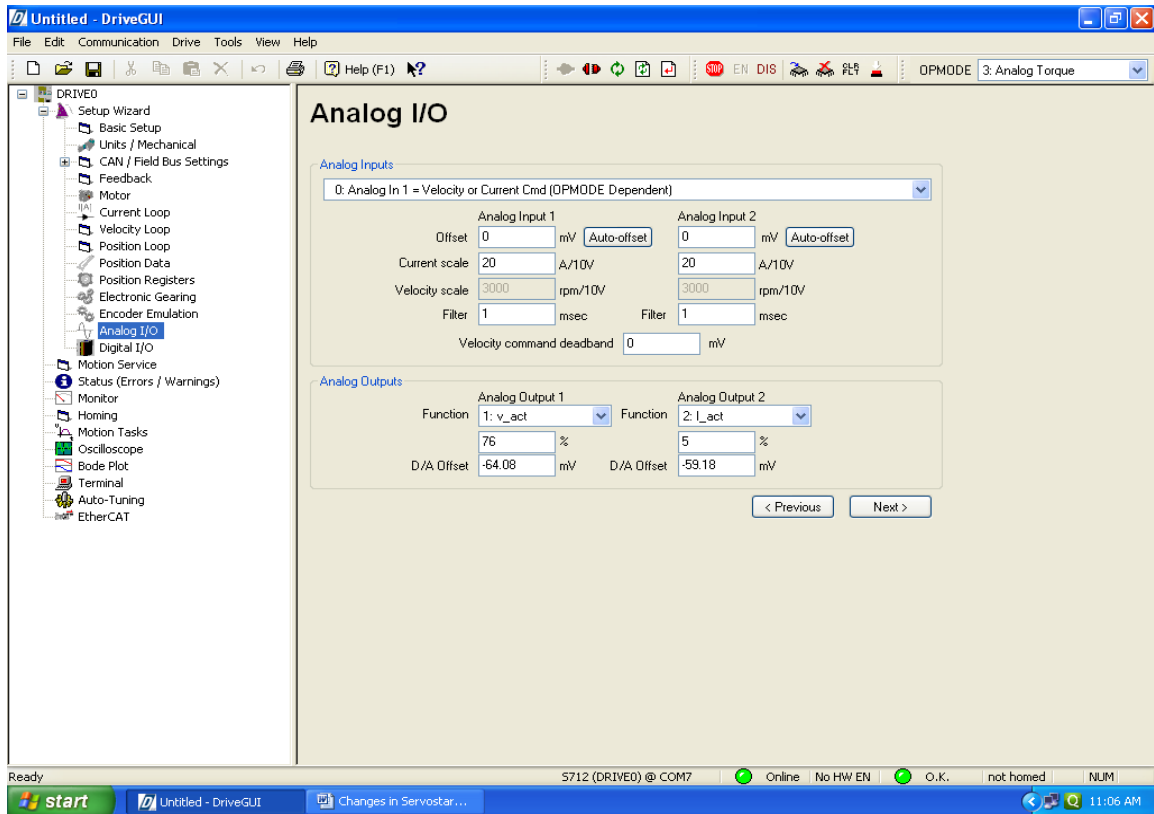
Current and Tacho settings in Drive GUI

Figure25: Settings for Current and Speed scaling in DRIVEGUI software

4.6 Cable duct wiring details

Cable duct is mounted on top of shielded room. All cables coming down from azimuth and elevation platform are routed through cable duct before going to BLDC rack and control rack. Purpose of cable duct is to keep cables sorted and provide require separation between cables. Figure 26 shows picture of cable duct mounted on shielded room.

Figure26: Image of cable duct mounted on shielded room

Following list of cables are routed through cable duct.

1. AZ Encoder
2. AZ RH motor
3. AZ LH motor
4. Wind east
5. EL UP motor
6. EL DN motor
7. AZ limit switch
9. AZ RH resolver
10. AZ LH resolver
11. Wind west
12. EL UP resolver
13. EL DN resolver
14. FPS limit switch
15. FPS encoder
16. paint switch
17. El limit switch1
18. El limit switch2
19. Thermostat

4.7 Power panel installation

In PMDC system four 13.5KVA transformers are used to power each drive controlling brushed motors. In BLDC system four 13.5KVA transformers are replaced by one 15KVA transformers. Power panel consists of 3phase contactor which makes connection between BLDC rack and 15KVA transformer. Contactor is governed by timer which will provide 3phase supply to rack after stipulated time period defined by user.

Power panel also consists of single phase isolation transformer which is used to provide power to control rack. Single phase supply is associated with timer and contactor circuitry.

Step down transformer of primary 230Vac to secondary 55Vac is mounted onboard which provides supply voltage to stow panel circuitry. Figure27 shows image of power panel mounted and Figure28 gives circuit schematic details of single phase power and Figure29 gives circuit schematic details of three phase power.
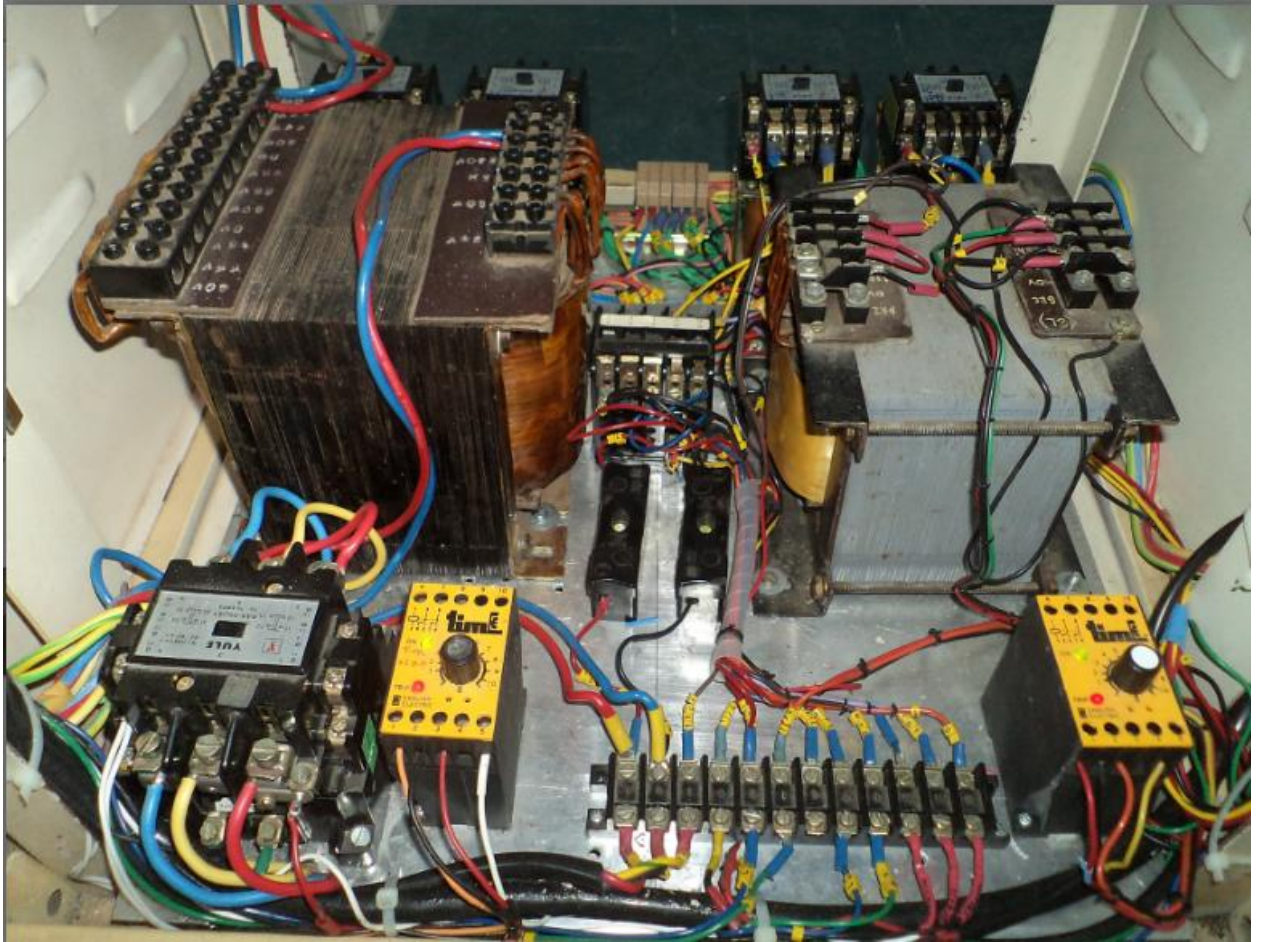
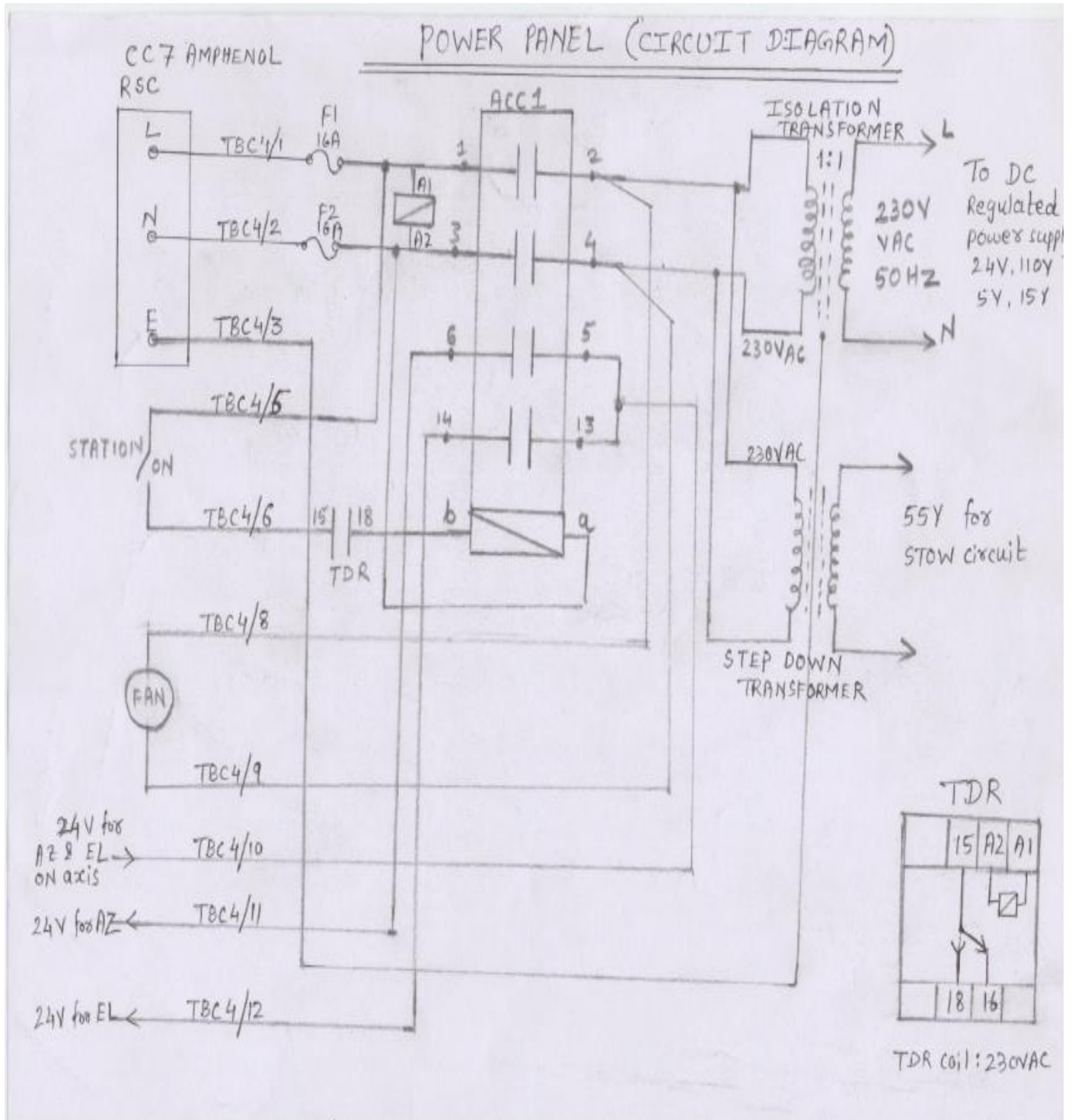Figure27: Power panel mounted in control rack

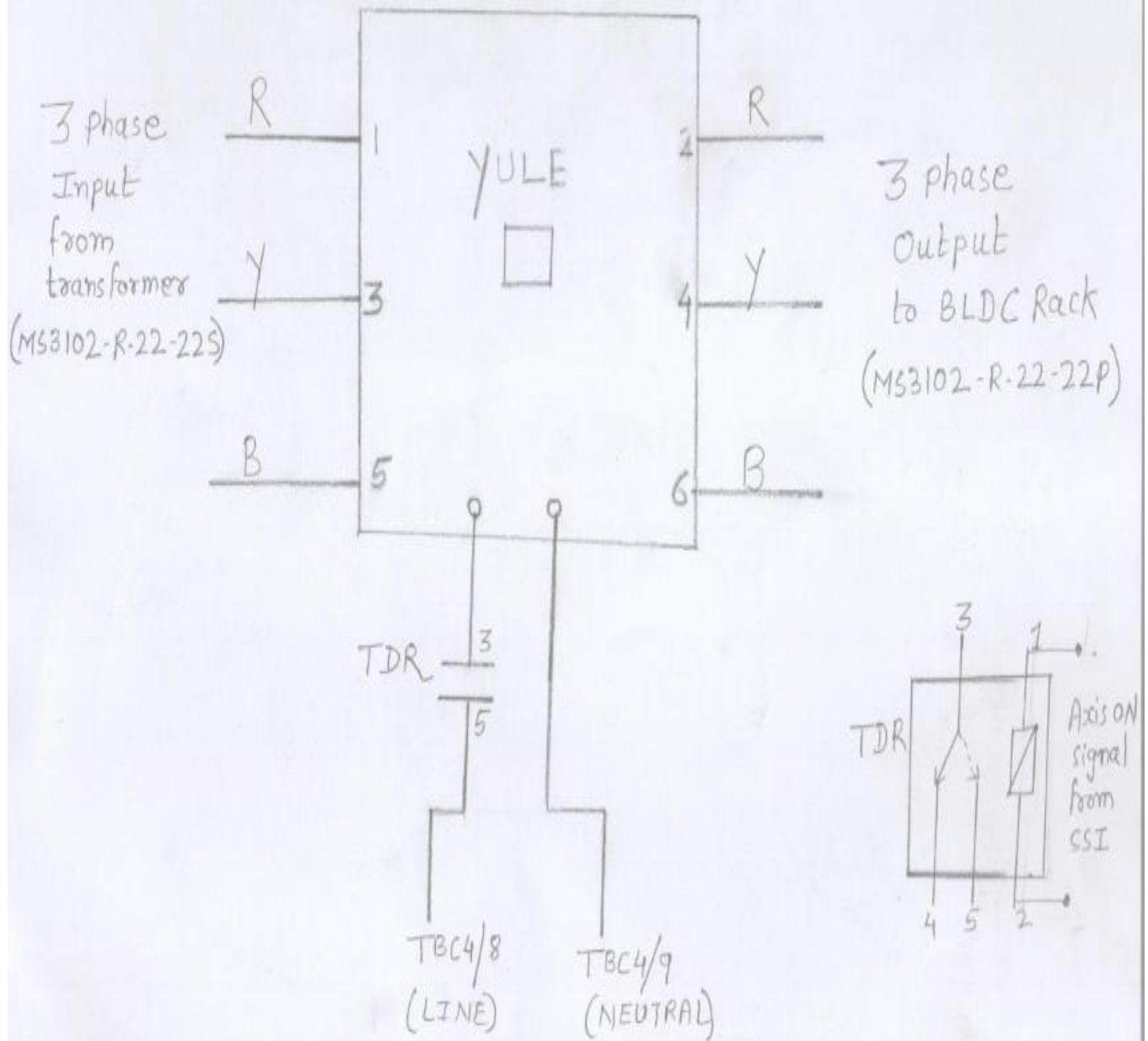Figure28: Circuit schematic of power panel (Single phase)

Figure29: Circuit schematic of power panel (Three phase)

4.8 Grounding details for BLDC system

Figure30 shown below gives details of grounding details after commissioning of new BLDC system
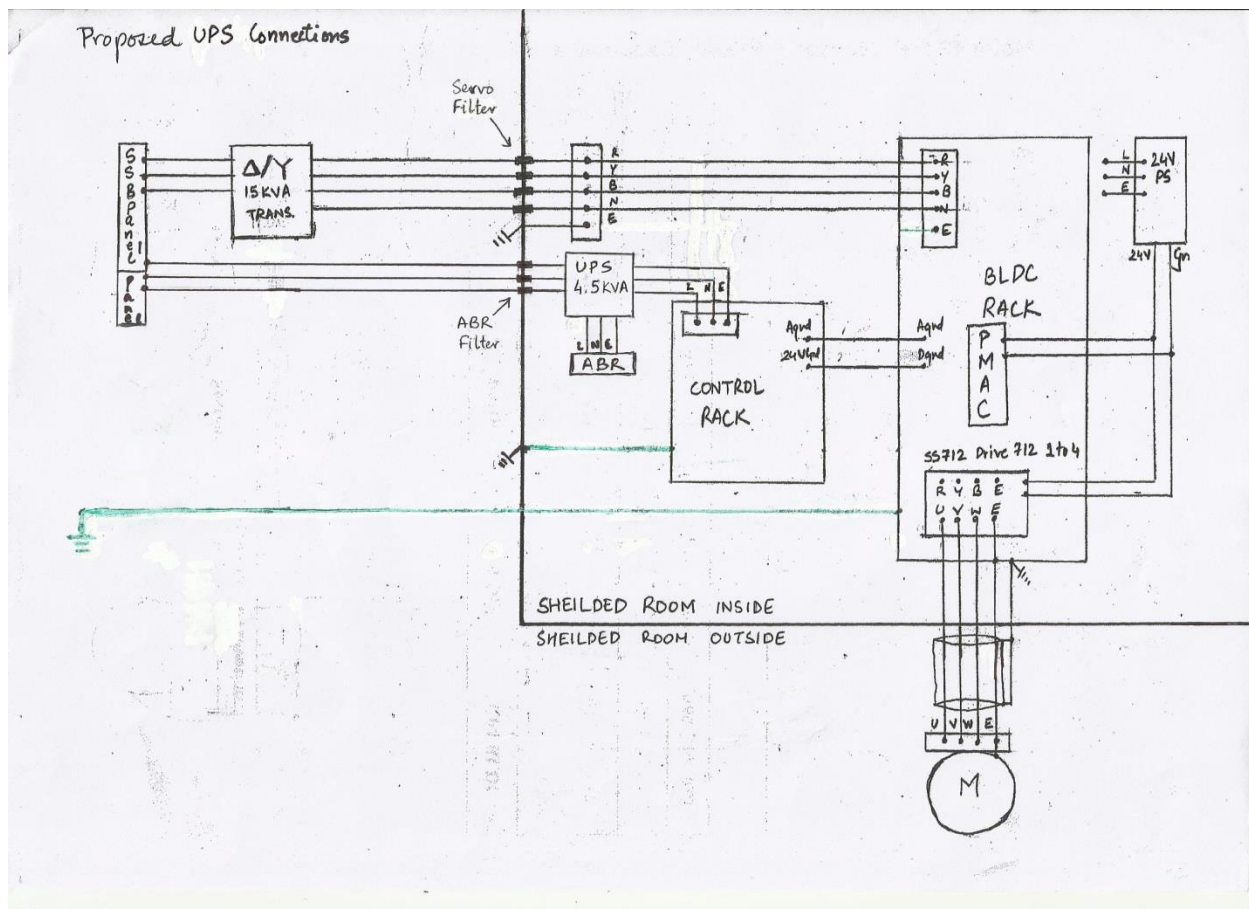

Figure30: Grounding details of BLDC system

Note:
After the installation of PC based Servo computer in PC 104 there is a need to give the servo control rack power backup in case of main power failure. There is a proposal for installation of a 4.5 KVA UPS which will provide UPS power to both Servo control rack and ABR rack.

*Circuit details of Figure30 referred from [5]

4.9 Stow panel installation

Stow circuitry is used to keep the dish steady in parked position. It consists of two stow pins driven by two ½ HP motors. When high winds are experienced (>40kmph) antenna dish is brought at parking position (Elevation angle at 90 degrees). To keep antenna firmly in this position it is locked by two stow pins. To drive two ½ hp motors controlling stow pins, stow panel circuitry is commissioned in control rack. This panel was earlier mounted in old Elevation drive rack. Stow panel circuitry is powered by a step down transformer of 230V-55V associated with bridge rectifier circuit. Circuit schematic of stow panel is shown in Figure31 on next page
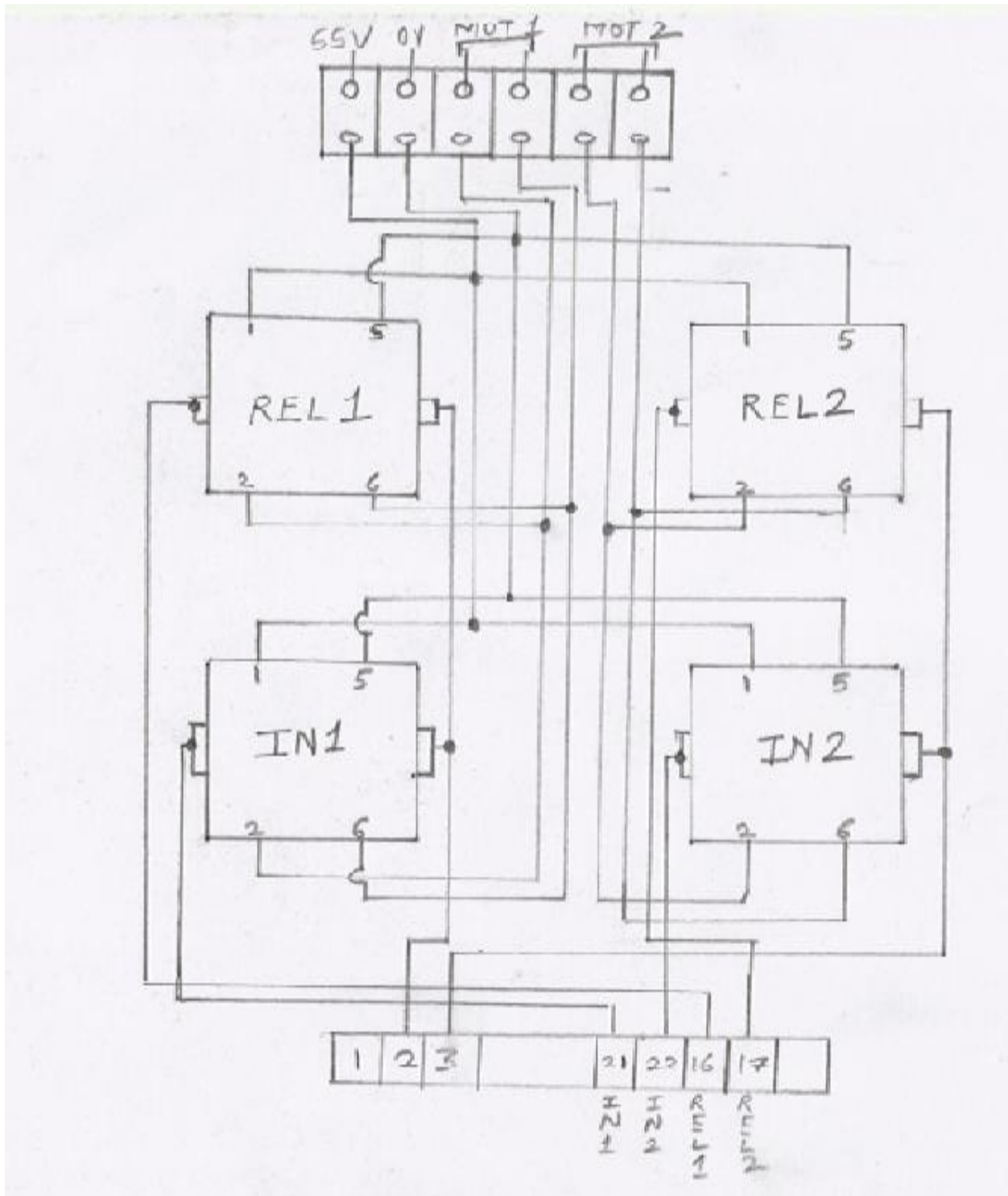
Figure31: Stow panel circuitry

5. Post installation procedures

5.1 Motor run test

Scope of Test:
Motor run test involves checking Tacho and current values for different voltage inputs. These readings are compared with 'motor run test' readings done before BLDC system is installed.

Equipment's used: Digital multi-meter

Procedure:
1. Antenna setup is as shown in Figure32
2. Put antenna in manual mode using switch on servo system console.
3. Assure that speed pot on console panel is pointing toward zero
4. Release brakes of axis you want to perform test (Azimuth or Elevation)
5. Connect DMM probes to I/P HI pins on monitor card
6. Rotate pot on console till DMM shows 1V
7. Note down tacho and current readings in Table1 by connecting DMM probes to Tacho-HI and current points on monitor card
8. Note down current and speed shown by HHT in Table1
   Commands to check tacho and currents in HHT:
   M, D
   D (It will show currents for M1, M2, M3 and M4)
   Press '/' key
   (It will show speeds for M1, M2, M3 and M4)
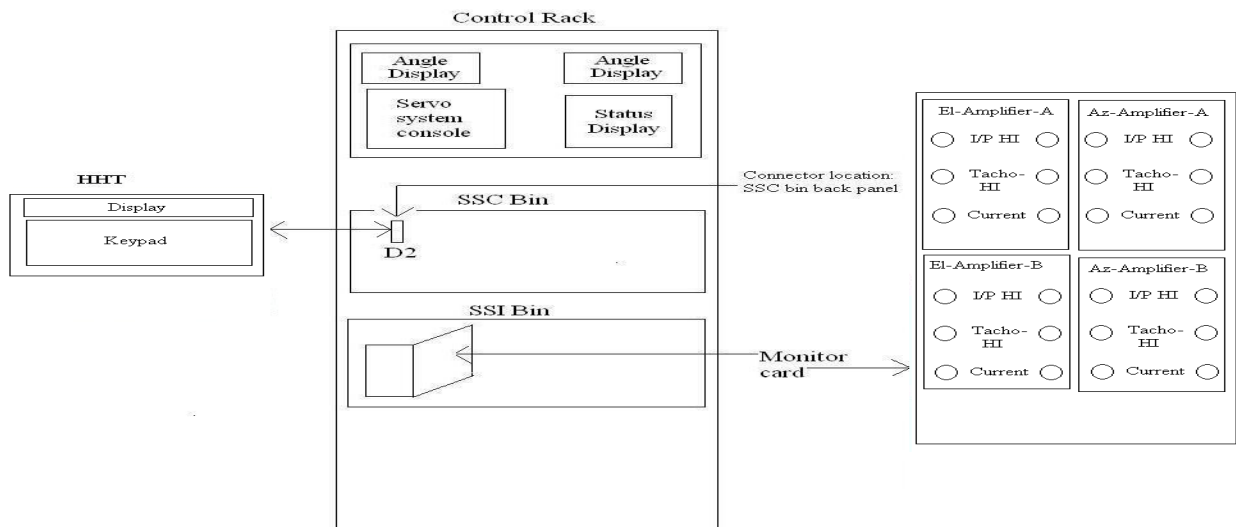9. Repeat steps for different I/P HI voltage

Figure32: Motor run test setup

Antenna: …………………   Date: …………….

Azimuth/Elevation

Table15: Motor run test

I/P (Volts)	ANT DIR	M1 Tach V	M 2 Tach V	M 1 Cur. mV	M 2 Cur. mV	Amp1 A	Amp2 A	HHT Cur. 1 A	HHT Cur.2 A	HHT Spd1 Rpm	HHT Spd2 Rpm
1V	CW										
2	CW										
3	CW										
4	CW										
5	CW										
Max	CW										
1	CCW										
2	CCW										
3	CCW										
4	CCW										
5	CCW										
Max	CCW										

NOTE:

For input voltage: 1V to 5V: Operate in manual mode

For maximum input voltage: Use HHT in Local mode

Hand Held Terminal commands used:

M,C

H,A (Hold command to Azimuth axis)

P,A,deg:min:sec (To give position command)

5.2 Interlock test

Scope of test:

Interlocks are used in antenna for its fail safe operation. Interlock test is done to check status of limit switches (whether it is working or not) and position where limit hit occurs. Test is done again after BLDC system has been installed to check if there is any damage after BLDC installation.

Procedure:
1. Figure2 shows limit recovery card mounted in control rack which shows limit hit indication
2. Put antenna in manual mode using switch in servo system console
3. Release brakes of axis (Azimuth or Elevation) for which you want to perform Interlock test.
4. Rotate antenna by adjusting manual input pot to full scale. Antenna will rotate and hit pre-limit and stop the Antenna by applying brakes. This will be indicated by blinking red led in limit recovery card
5. To move further to hit final limit you need to bypass pre limit. Pre limit switch can be bypassed by keeping it continuously pressed on limit recovery card. To start antenna rotation bypass pre limit switch and release brakes. Antenna will rotate further and hit final limit. Limit hit will be indicated by red led blinking
6. Follow this procedure for all interlock limit switches and note down remarks in Table2.1 and Table 2.2
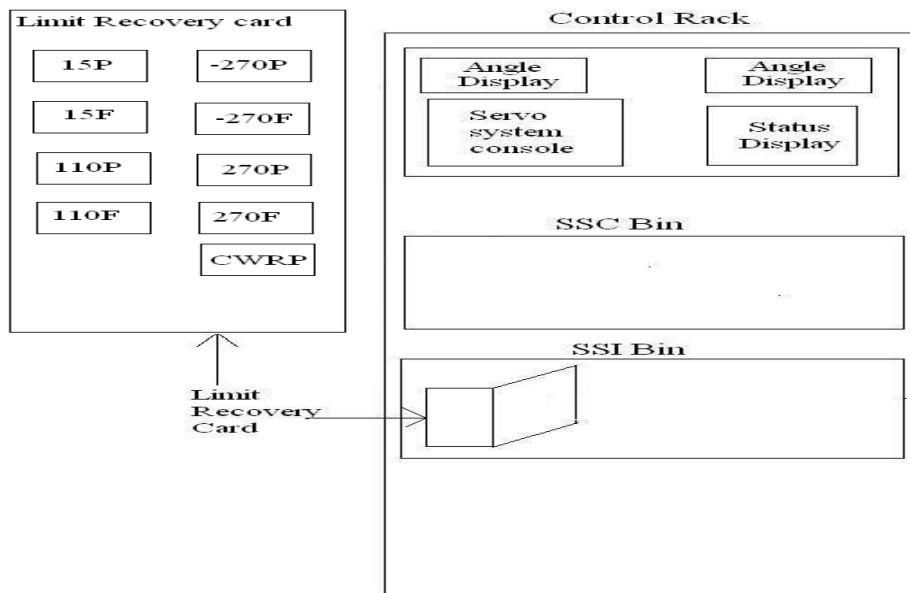   Note: Limit switch will also be indicated on status display

Figure33: Limit hit indication in Limit recovery card for Interlock test

Table16.1: Elevation interlock limit switch test

Sr No.	Limit	Remarks	Position
1	15P	OK/Not OK	
2	15F	OK/Not OK	
3	110P	OK/Not OK	
4	110F	OK/Not OK	
5	STP	OK/Not OK	
6	90D	OK/Not OK	
7	IN1	OK/Not OK	
8	IN2	OK/Not OK	
9	REL1	OK/Not OK	
10	REL2	OK/Not OK	
11	MOVL1	OK/Not OK	
12	MOVL2	OK/Not OK	
13	AOVL-EL	OK/Not OK	

Table16.2: Azimuth interlock limit switch test

Sr No.	Limit	Remarks	Position
1	+ 270P	OK/Not OK	
2	+270F	OK/Not OK	
3	-270P	OK/Not OK	
4	-270F	OK/Not OK	
5	ZERO Deg	OK/Not OK	
6	CWRAP	OK/Not OK	
7	MOVL1	OK/Not OK	
8	MOVL2	OK/Not OK	
9	AOVL-AZ	OK/Not OK	

5.3 Locked rotor frequency test and step response test in velocity loop

BLDC System

Equipments required:

1. Hand held terminal (HHT).
2. Grounding cable for AIO card.
3. Tool kit with jewel set screwdriver.
4. Laptop with Pmacplot32pro and Pwin32pro (+ power cable)
6. USB cable (To connect laptop with PMAC controller)
7. BNC connector cable with D type connector (To connect the signal generator output to PMAC analog input)

Procedure:

1. Figure34 shows detailed block diagram used for doing LRF test in BLDC system. Put antenna in Manual mode.
2. Apply brakes to both axes (Servostar displays P12 for both axes).
3. Connect the laptop/PC to the PMAC controller using USB cable.
4. Run Pwin32pro.
5. In Pwin32pro window, select Setup -> Force all windows to device number -> PMAC-00 USB plug & play and click OK. This will setup the communication between the laptop/PC and PMAC controller.
6. Go to Files -> Download files -> LRF_Az_El_Velocity.pmc -> OK. This will download the plc file desired for this experiment (File available in CD contents).
7. In the Pwin32pro terminal window, type following commands to enable the azimuth axis motors:
   #1o0 #2o0
   5j/
   While, these commands for elevation axis motors:
   #3o0 #4o0
   6j/
8. Open Pmacplot32pro. In the Pmacplot32pro window, click "Detail Plot".
9. Then click on "Items to Gather" to "Gather Period" →"Source 1"→ Click >>→ "M-variable" → Enter the M-variable number for selected motor (M-variables are given at the end of this document) → Click >>→ The address gets displayed → Click "OK" →"Source2" → Click >>→ Mark "M variable"→ Enter input variable number → Click>>→The address gets displayed → Click "OK".
10. Then click on "Scaling and Processing"→ "Source A" → "Edit" →Make following settings:

   i. Item name: Motor velocity"
   ii. Unit: counts/sec
   iii. Scale: 000326
   iv. Differentiate: Once.
   Then, Click "OK" → "Source B" → "Edit" → Again make the following settings:

61

       i.   Item name: Input
      ii.   Unit: counts
     iii.   Scale: 0.000555
    Then click "OK".

11. Click on "Items To Plot"→ "Edit" →Make following settings:

      i. Horizontal Axis: Time
      ii. Left Vertical Axis: Motor Velocity
      iii. Right Vertical Axis: Input
      Then, click "OK"→click "OK".

12. Now click "Define Gather Period".

13. Switch o_ the SSC rack power. Remove the at ribbon cable (FRC) connector from the analog input/output (AIO) card of station servo computer (SSC) bin and replace it with the grounding FRC cable. Connect the other end of grounding FRC cable to a suitable grounding point and switch on the SSC rack power again.

14. In the station servo computer (SSC) rack press AZON button for enabling azimuth axis and ELON for enabling elevation axis. Servostar shows E12 on the display of both axes.

15. Go to Pwin32pro terminal window and enter following commands

    p106 = 0.1
    p105 = 7
    p104 = 290
    p108 = 25000
    p100 = 2 # for azimuth axis
    OR
    p100 = 3 # for elevation axis

16. In Pmacplot32pro window, click Begin Gathering and at the same time press the output button of the signal generator.

17. In the Pwin32pro window, check for counts changing for 1st or 2nd motor in azimuth axis and for 3rd or 4th motor in elevation axis.

18. After approximately 290 sec, press End Gathering.

Table17: LRF test results

Parameters obtained from LRF test			
		Actual	Expected
1	Locked Rotor Frequency	Fr		1Hz

BLDC Rack

Laptop

USB
Cable

PMAC

Note:
1. LRF PLC code is programmed in PMAC

2. Data logging done in Laptop using PMACPlotpro
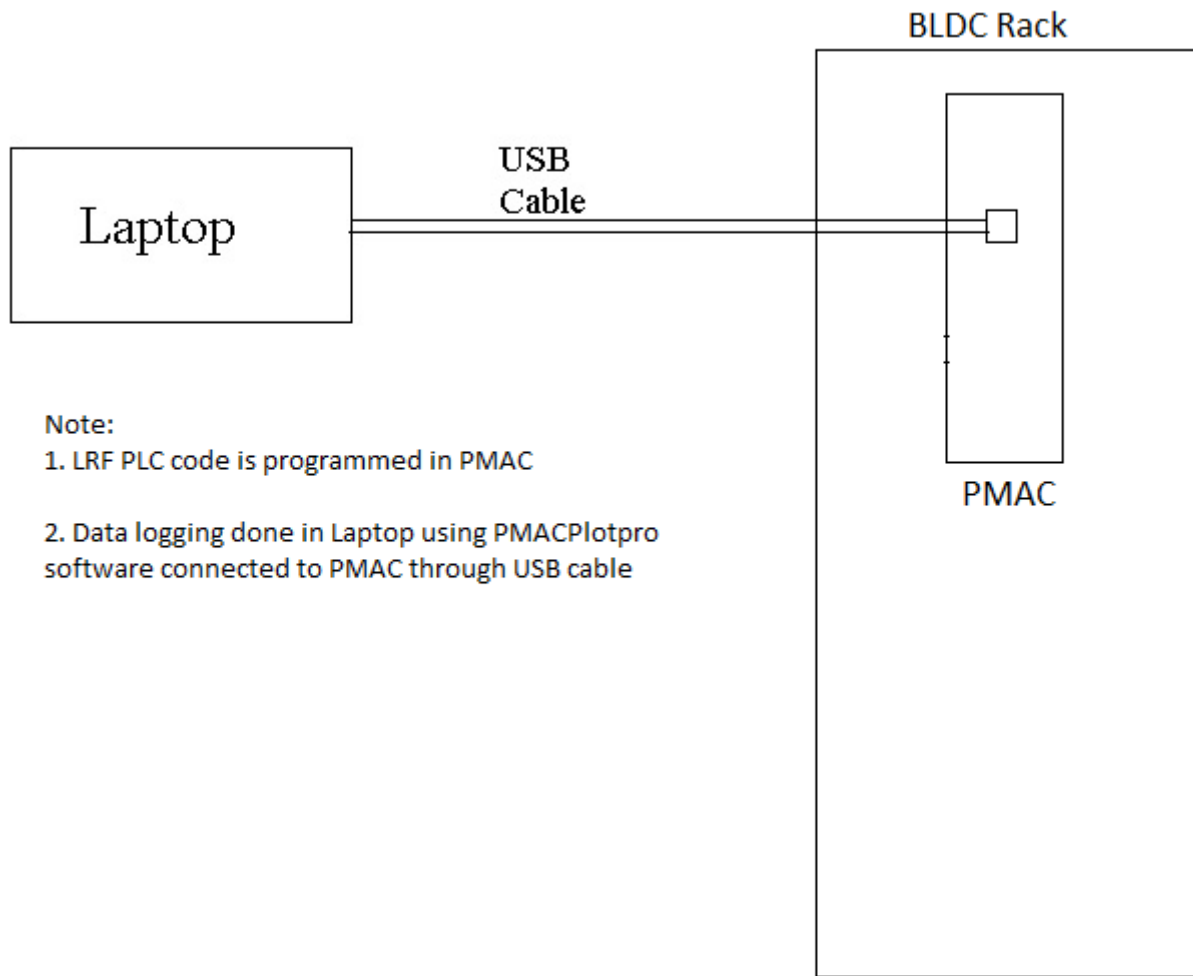software connected to PMAC through USB cable

Figure34: Block diagram of LRF test setup for BLDC system

Step response test for velocity loop

Procedure
1. Figure35 below shows block diagram of setup used. Now put antenna in Manual mode.
2. Apply brakes (Servostar displays P12).
3. Switch on the multi output Spectron power supply, set it to 200 mV and switch it off again.
4. Remove channel-7 connector from Turbo PMAC and co
5. Run Pwin32pro.
6. Open Pmacplot32pro.
7. In the Pmacplot32pro window, click "Detail Plot".
8. Then click on "Items to Gather" to "Gather Period" → "Source 1"→ Click >> → "M-variable" → Enter the M-variable number for selected motor (M-variables are given at the end of this document) → Click >> → The address gets displayed → Click "OK" → "Source2" → Click >> → Mark "M variable" → Enter input variable number → Click >> → The address gets displa yed → Click "OK".
10. Then click on "Scaling and Processing" → "Source A" → "Edit" → Make following settings:
       i. Item name: Motor velocity"
       ii. Unit: counts/sec
       iii. Scale: 000326
       iv. Differentiate: Once.
       Then, Click "OK" → "Source B" → "Edit" → Again make the following settings:
       iv.   Item name: Input
       v.   Unit: counts
       vi.   Scale: 0.000555
       Then click "OK".
11.Click on "Items To Plot" → "Edit" → Make following settings:
       i. Horizontal Axis: Time
       ii. Left Vertical Axis: Motor Velocity
       iii. Right Vertical Axis: Input
   Then, click "OK"→ click "OK".
12. Now click "Define Gather Period".
13. In the station servo computer (SSC) rack press AZON button for azimuth axis and ELON for elevation axis.
14. Servostar will display P12 on the display of both axes.
15. In Pmacplot32pro window select "Begin Gathering", then press the output button of the Spectron multi output power supply.
16. In the Pwin32pro window check for counts changing for 1st or 2nd motor in azimuth axis and for 3rd or 4th motor in elevation axis.
17. After 100 s, press "End Gathering".
18. Select "Upload data".
19. Click "Plot Data".
20. Save the Plot as .ppl file (default data format for Pmacplot32pro) and text file. The text file can be used for the plotting the data using Matlab.
PMAC variable values:
1. Azimuth axis BLDC motors

1.1. Motor 1-M variable : m162

1.2. Motor 2-M variable : m262

2. Elevation axis BLDC motors

2.1. Motor 3 M-variable : m362

2.2. Motor 4 M-variable : m462

3. M-variable for Input voltage to velocity loop
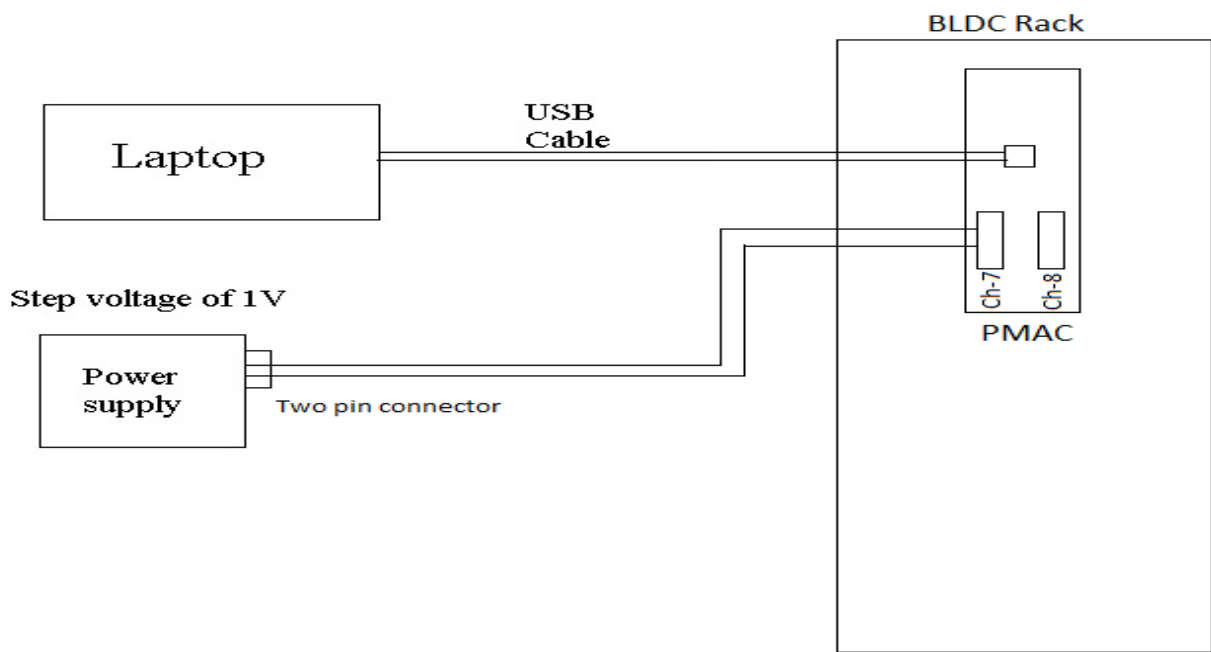
3.1. Azimuth: m5063

3.2. Elevation: m5064

Figure35: Block diagram of step response test setup for BLDC system

5.4 Step response test for position loop

Scope of test:

Test is done to understand transient characteristics of antenna system for different step input signals

Procedure:

1. Test is done by giving 1 degree and 10 degree position step from control room.
2. Data file obtained from control room is used to plot step response in GNUPLOT.
3. Transient response parameters are calculated and tabulated as follows,

Table18: Step response test results

Parameters obtained from step response				
Sr no	Description	Abbreviation	Actual	Expected
1	Peak overshoot(%)	Mp		
2	Peak time	Tp		
3	Settling time	Ts		

5.5 Tracking test

Scope of test:

Test is done to check whether Antenna tracking before and after BLDC installation is same or not.

Procedure:
1. Track command is given from control room for different tracking speeds,
   Azimuth: 15 arcmin/min and 150 arcmin/min
   Elevation: 5 arcmin/min and 15 arcmin/min
2. Date logged by control room is plotted using GNUPLOT.
3. Tracking error is plotted as error = target position – Actual position

5.4 RFI test:

Scope of test:
RFI test is done to check radio emission levels from old antenna system. Results obtained are kept as reference and compared with RFI test done for BLDC system post installation

Procedure:
Test is done by RFI/OFC group. For details please refer to document [4]

References:

[1] GMRT servo system – Design manual
http://tech1.gmrt.ncra.tifr.res.in/thiyagu/SERVO/designmanual.pdf

[2] Analysis and comparison of locked rotor frequency for BLDC and PMDC motor system on GMRT antennas by Aditi Bhatt
http://tech1.gmrt.ncra.tifr.res.in/thiyagu/BLDC/lrf_report.pdf

[3] Wiring and cables for EMC cabinet by M/S Maccon
http://tech1.gmrt.ncra.tifr.res.in/thiyagu/BLDC/rack_wiring.pdf

[4] BLDC Servo System RFI Measurement Report by RFI Group, GMRT
http://tech1.gmrt.ncra.tifr.res.in/thiyagu/BLDC/E05_rfi_report.pdf

[5] Isolation of Power Ground and Low Power Electronics in BLDC System by Amit Kumar, Servo group
http://tech1.gmrt.ncra.tifr.res.in/thiyagu/BLDC/note_on_grounding.pdf

[6] GMRT Station Servo Computer – Micro Computer Boards Hardware Reference
http://tech1.gmrt.ncra.tifr.res.in/thiyagu/servo/hardware_ref.pdf