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GMRT servo system : overview of the upgrades

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Abstract. The servo system of the GMRT, designed in the early 1990s by BARC and subsequently commissioned in the antennas by 1996, is a classical nested loop control system. Some of its major subsystems are undergoing significant upgrades to increase reliability, reduce maintenance and overcome obsolescence of components. These include the solid-state interlock system, a PC104 based servo control computer, and advanced BLDC drives and motors.

Keywords : Servo systems, GMRT, BLDC, PC104, Interlocks, Controller

1. Introduction to the Servo Control System of the GMRT

The GMRT (Swarup et al. 1991) has a sophisticated servo system that was designed in the early 1990s by the Reactor Control Division of BARC (GMRT Servo Design Manual 1996). An outer position loop, a speed loop and the two current loops constitute a classical nested control system for each of the axes of the existing GMRT Servo System (as shown in Fig. 1). The position loop is implemented in a 8086-based computer which in real time computes digital Tustin transforms every 100 ms on the position error. The speed loop is implemented in an Op-Amp based circuitry, while the current loops sit within SCR- based amplifiers (converters). The safety interlocks system, initially built around electromechanical relays, prevents antennas from crossing limits and continuously checks all the safety parameters of each of the subsystems. It also provides isolation between low power electronics and high-power electronics. For the elevation axis, a stowing system exists with two stow motors which insert two rigid pins into sockets of the counter weight of the antenna to hold it parked and steady amidst high winds.

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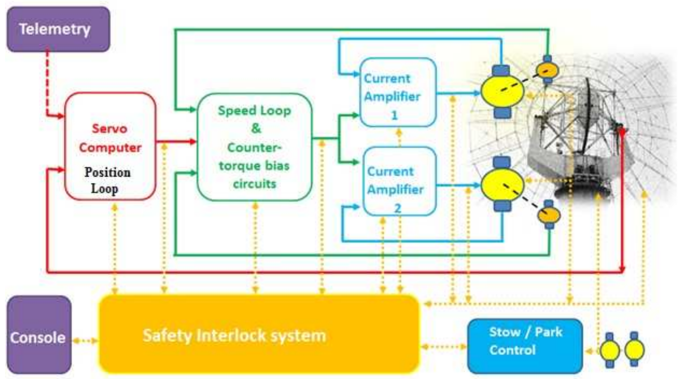

Figure 1. Nested control loops of the GMRT servo system.

2. Motivations and challenges for the upgrades

The servo system of the GMRT was designed in the early 1990s by BARC, and subsequently commissioned in the antennas by 1996. In the last decade and half of operations, some problems in some of the subsystems have led to significant reliability issues. Table 1 gives statistics of various problems faced by the servo system over the years.

Table 1. Problems in the GMRT servo system and their statistics over the years.

Subsystem	Problem Statistics	Nature of the Problem
1. Relay Interlocks	40% of all the servo problems	Loose contacts, corrosion of contacts
2. PMDC motors	25% of all the servo problems	Carbon dust accumulation leading to short-circuit in armature
3. Servo computer	15-20% of all the servo problems	Obsolescence of components, dated software in Pascal and assembly language

These problems have led to fairly frequent breakdowns in antenna functioning, posing questions on reliability of the system and breaks in observations. At the first level, motivation for the upgrades surfaced due to such problems. An additional aim of the upgrades has been better functionality and harnessing of the latest technologies. The main challenge for the upgrades was to use available manpower for the design and development of reliable new sub-systems and later commissioning of these, while simultaneously supporting operations of the existing telescope. Further, limited upgrade time, shared amongst various other upgrades of the GMRT, in the midst of continuous observations poses another challenge (Gupta, 2014). The upgrades are designed so as to leave minimal RFI footprint. Phased migrations of various subsystems also raised issues of maintenance and upkeep of the overall system, challenging for the limited manpower.

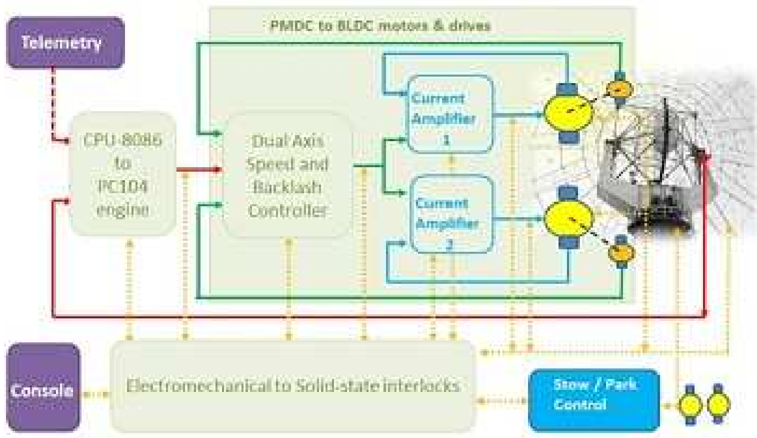

Figure 2. Illustrating the upgrades in the various subsystems of the GMRT servo system.

3. Summary of the upgrades

Figure 2 illustrates the various upgrades that are being executed in the servo system. These upgrades keep the original structure of the servo system unchanged; only individual subsystem are undergoing improvements, keeping the inputs/outputs and the overall system performance unchanged. The details are as follows :

(i) Electromagnetic Relay interlocks to Solid-state interlocks: In the XIth Plan (2007-2012), electromechanical relay interlocks were gradually replaced with solid-state interlocks (SSI). The SSI design used reliable TTL-family logic ICs, programmable logic devices and opto-isolators. It derived all its logic from the proven logic of the relay interlocks over the years. The SSI system has now been installed in all the 30 antennas.

(ii) CPU86 to PC104 engine in the first phase of servo control computer: PC104 is an off-the-shelf advanced CPU based on latest technolog, peripherals and the ISA bus architecture. A significant advantage of the PC104 engine is the ability to run with a real-time open-source operating system such as RTAI Linux and plethora of other software development tools. In the first phase of upgrading from the 8086 based CPU, the PC104 was integrated with a bridge-card to use the current set of peripheral cards. The entire Pascal and assembly code was translated into C, and was validated extensively. Additional software tools for logging all the variables, generation of test-profiles, self-tests etc were developed.

The PC104 based engine has been successfully interfaced with external host such as the GMRT telemetry system on RS-232 protocol; as well as it is also working with the Control and Monitoring System of the 15m antenna on Ethernet. Currently, the

PC104 system has been installed on 10 GMRT antennas, and is progressing smoothly towards completion of all 30 antennas. In the second phase of the upgrade, the entire servo control computer will be replaced by a newly designed system named as Generic Antenna Controller Board (GACB).

(iii) PMDC motors to BLDC motors with a dual axis backlash controller: The BLDC motors and their drives along with a dual axis backlash controller, to replace the existing permanent magnet DC motors and drives, form the most ambitious upgrade within the servo system. These motors are practically maintenance free; but, they require very intelligent drives. Kollmorgen-make drives and motors were selected as one-to-one replacement for the old PMDC motors and their SCR amplifiers. A multi-axis programmable controller has been used as a speed loop and backlash controller for implementing speed loops for both the axes. Since the commutation takes place electronically in this new system, EMI generation within the drives forms a main concern for the use of the BLDC systems. An EMI compliant cabinet was tested for its shielding attenuation and radiated emission as per the IEC standards in Munich, Germany. Also the earthing arrangement for motor cables was given attention : all the motor power cables were earthed every 1.5 m to avoid any radiation from the cables. Each antenna was tested for EMI compliance as per the GMRT standards before and after the BLDC installation and commissioning.

Further, the BLDC equipped antennas underwent validation for their control stability and various performance parameters. Each antenna was extensively tested for LRF, position loop and speed loop, tracking performance and was compared to the earlier system with PMDC motors. Currently, 8 antennas have been upgraded with the BLDC system, and all the 30 antennas are targeted for completion by the end of 2016.

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