National Centre for Radio Astrophysics

Internal Technical Report

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Note on PC104 and 8086 Compensator Performance in GMRT Antenna

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Description

The motivation of writing this note is during the installation of PC104 Station Servo Computer (SSC) in GMRT antennas, various filed tests was carried out to verify the functionality of different sub-system modules of the ported software like antenna controller, communication module, compensator module, soft-start module, , azimuth (AZ) and elevation (EL) axis state machines, internal software timers, message passing and mail boxes communication, while testing the PC104 software in C01 antenna the response of the various modules mentioned above are satisfactory but the compensator module response was not completely satisfactory, because this module response directly reflects in the form of structural dynamics.

For step responses of less than 1° the overshoots are approximately 10% for all antenna AZ and EL axis positions. But for larger step inputs the behavior of compensator was not same as the case (10% overshoot) above mentioned. As per the 8086 antenna control software, for different step inputs to antenna physical system the responses should be identical by considering same environmental and external disturbances, but the PC104 software behavior was not same. Because of larger overshoot for higher step commands, sometimes elevation axis down pre-limits is hit. This was happened in 25-3-2014 in following PC104 antennas C01, C02 and C08.

The above conflict in responses may roused due to the following reasons,

1. The discrete equations implemented in 8086 PASCAL software may be different from the PC104 software.
2. Implemented mathematical calculations and computations in 8086 and PC104 may differ.
3. The additional position slew switch in PC104 compensator module.
4. Programming bug and arrangement of rate limiters and saturation modules in program

The following cases describe the possibility of cause for the conflict in response and provide the remedies to be implemented in software.

Case 1: Discrete Equations

As per BARC GMRT design manual, the compensator implemented in 8086 PASCAL software is,

$$G\ s\ = \frac{\mathrm{G}_{21}\ \ 1 + \mathrm{sT}_{21}\ \ (1 + \mathrm{sT}_{22})}{(1 + \mathrm{sT}_{23})} \qquad \text{C.1}$$

The conversion of continuous s-domain transfer function into discrete z-domain was done with Tustin transformation in both cases. The detailed study was conducted in transformation and co-efficient calculations. We found that final discrete equation and co-efficient are same in both cases. (i.e PASCAL and PC104). This may not be the reason for conflict in overshoot for different step inputs.

Reference PC104 and 8086 compensator co-efficient comparison document (http://tech1.gmrt.ncra.tifr.res.in/thiyagu/PC104/report/pdf/co-efficient-comparison.pdf).

Case 2: Implementation in Software

8086: In 8086 hardware there is a provision for floating point math co-processor, but in GMRT CPU it was not used. All the floating point arithmetic was done using the "*fixed real format*" in software. It is specific to GMRT PASCAL software, in this format floating point number represented in signed 32 bit format with 16bit mantissa and 16 bit exponent in real hexa-decimal format. Floating point arithmetic was done using assembly programming and additional care was taken to avoid the overflows and underflows during arithmetic operations. There is a special file called "FXDRLPAS.ASM and FXDRLPAS.OBJ" this file should be linked to GMRT main source file, while creating GMRT.LSB and GMRT.MSB hex files. All the compensator input, output and co-efficient are treated in same *fixed real format.* (i.e. encoder current and target positions).

PC104: The upgraded station servo computer has in build floating point math co-processor, this hardware feature used while upgrading the PASCAL software. In this case existing compensator file was completely modified for co-efficient calculation as well as its inputs and outputs also. The way of discrete transfer function implemented in 8086 and PC104 are different. (i.e. In 8086, individual terms are multiplied and added subsequently because of limited CPU power and in PC104 all term multiplication and addition done in one go). In PC104 software co-efficient, target and current positions was treated in decimal numbers.

By considering the above two implementations in software there will be a minor change in final output will be there, because of *fixed real format* to *decimal format* conversion. This change in final output can be compensated by increasing gain values of filter constants (i.e. K_p& K_i)

Case 3: Position Slew Control

8086: This feature not available in PASCAL software.

PC104: This is the upgraded facility in PC104 software. It helps to acquire larger target position shortly by by-passing the compensator and injecting the full speed demand to speed loop. The entry and exit point to compensator was decided by position error. This feature introduce some jerky motion in position profile while entering and exiting from slew control this was observed in 15m antenna and some GMRT antenna. It may not contribute much change in overshoot and settling time. Presently this feature was disabled in C01, C12 and C11 antennas.

Case 4: Programming Bug

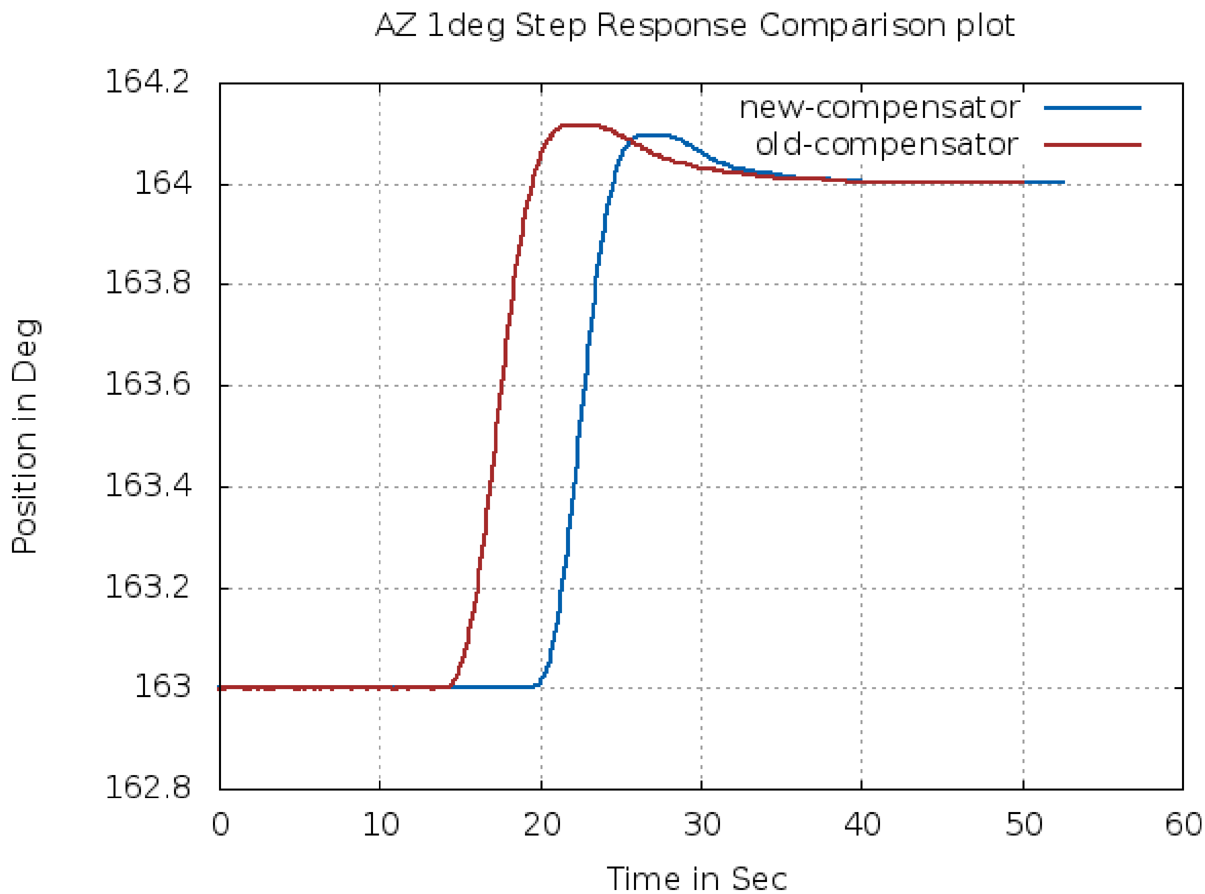
As mentioned in Case 2, the compensator file was completely modified in upgraded software as well as ways of implementing discrete equation is also different. In 8086 software each multiplication/division and addition/subtraction overflows and underflows are verified and accordingly final results are modified this values was compared with rated speed demand of individual axis. But in PC104 case all multiplications/divisions and addition/subtraction was done in one go and finally speed limiter values are checked, due to this internal memory variables like Yz0, Yz1,Yz2 and position errors are keep increasing beyond rated values. This is the major cause of higher overshoot (approximately 25% for 5° step). This bug was fixed in modified compensator and results are presented below.

Experiments in Antenna

The study was conducted in test setup with modified compensator file and a detailed experiment was conducted in C01 antenna during MTAC (2-April-2014 to 11-April-2014). The expected results are observed and presented below and it will be implemented in rest of PC104 antennas.

Comparison Results and Analysis

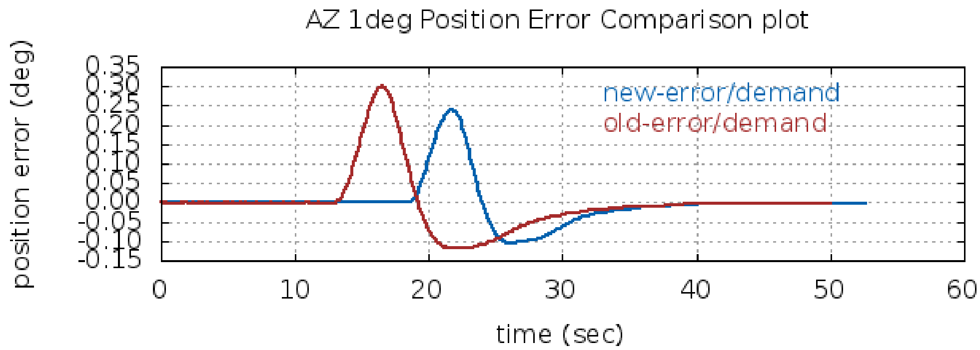
Case 1: Azimuth One Degree Step input

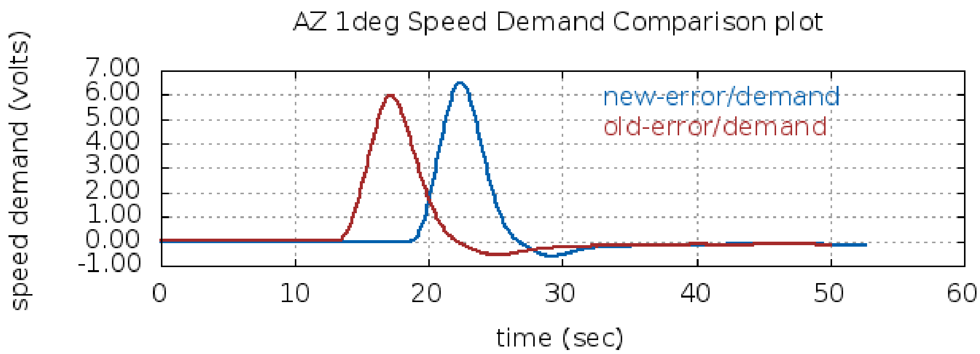


Time Domain Specification Comparison for one degree step

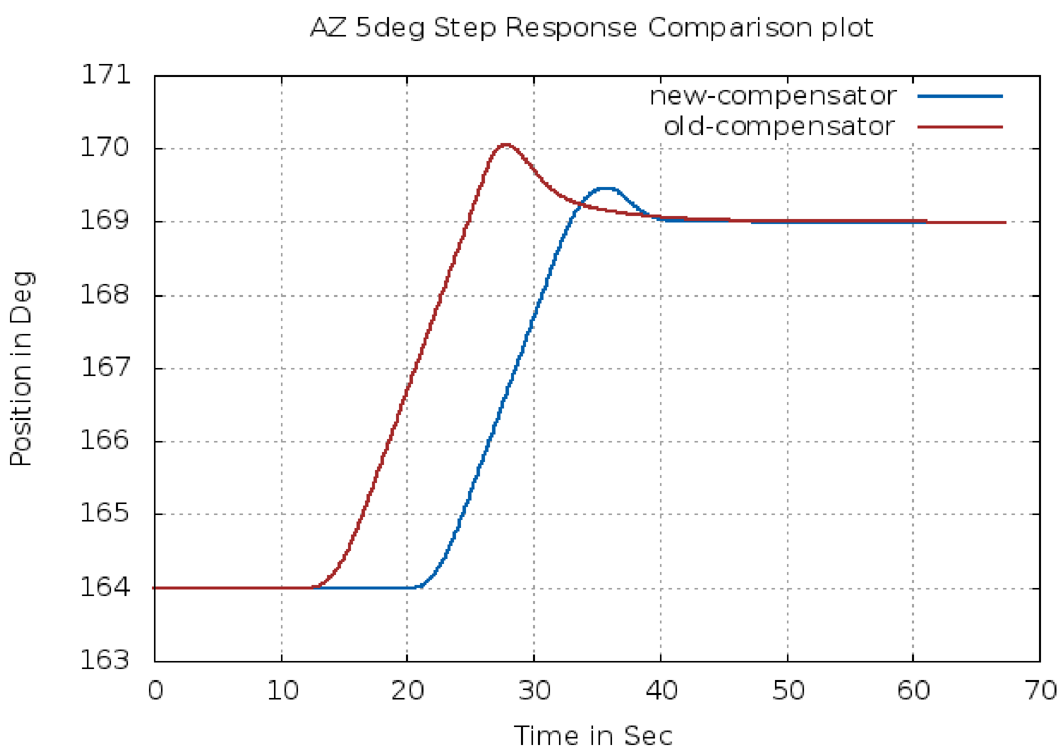
S.No	Description	New Type Compensator	Old Type Compensator
1	Delay Time (sec)	4.5	4.5
2	Rise Time (sec)	3.0	3.3
3	Peak Time (sec)	8.3	8.9
4	Settling Time (sec)	16.4	19.8
5	Peak Overshoot (%)	9.7427	11.6680
6	Peak Overshoot (arcmin)	5.8347	6.9910
7	Damping Factor	0.75	0.74

Position Error and Speed Demand Comparison for one degree step





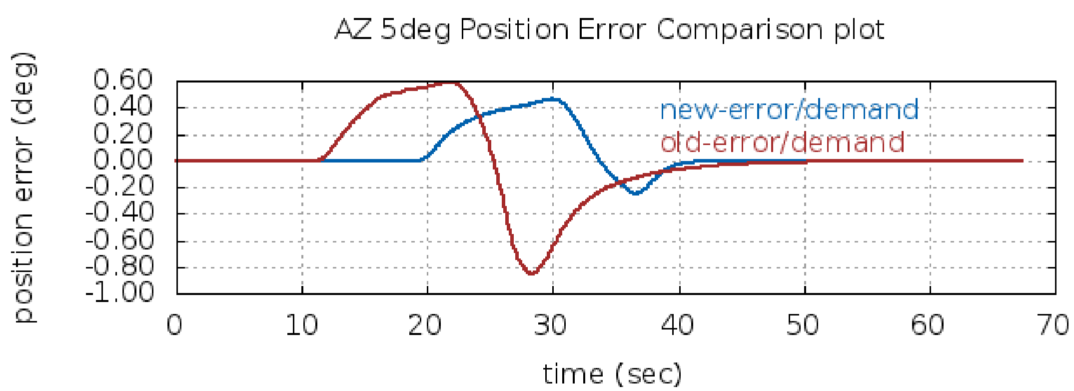
Case 2: Azimuth Five Degree Step input

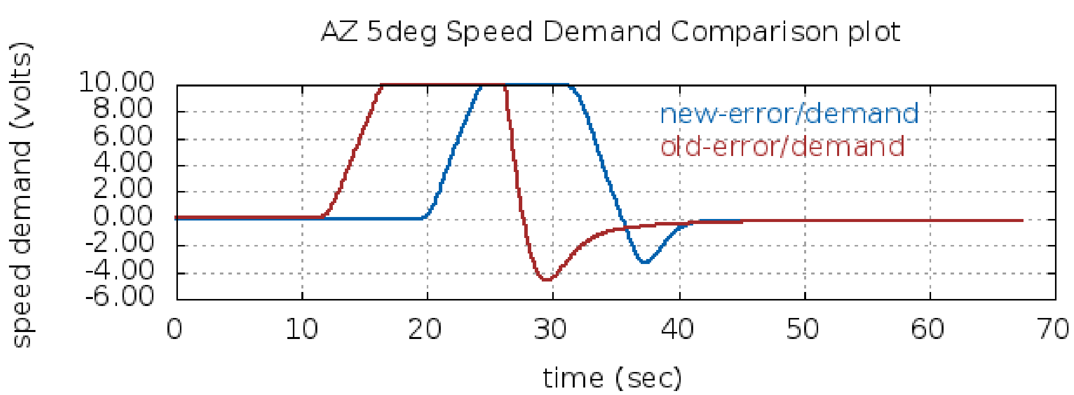


Time Domain Specification Comparison for five degree step

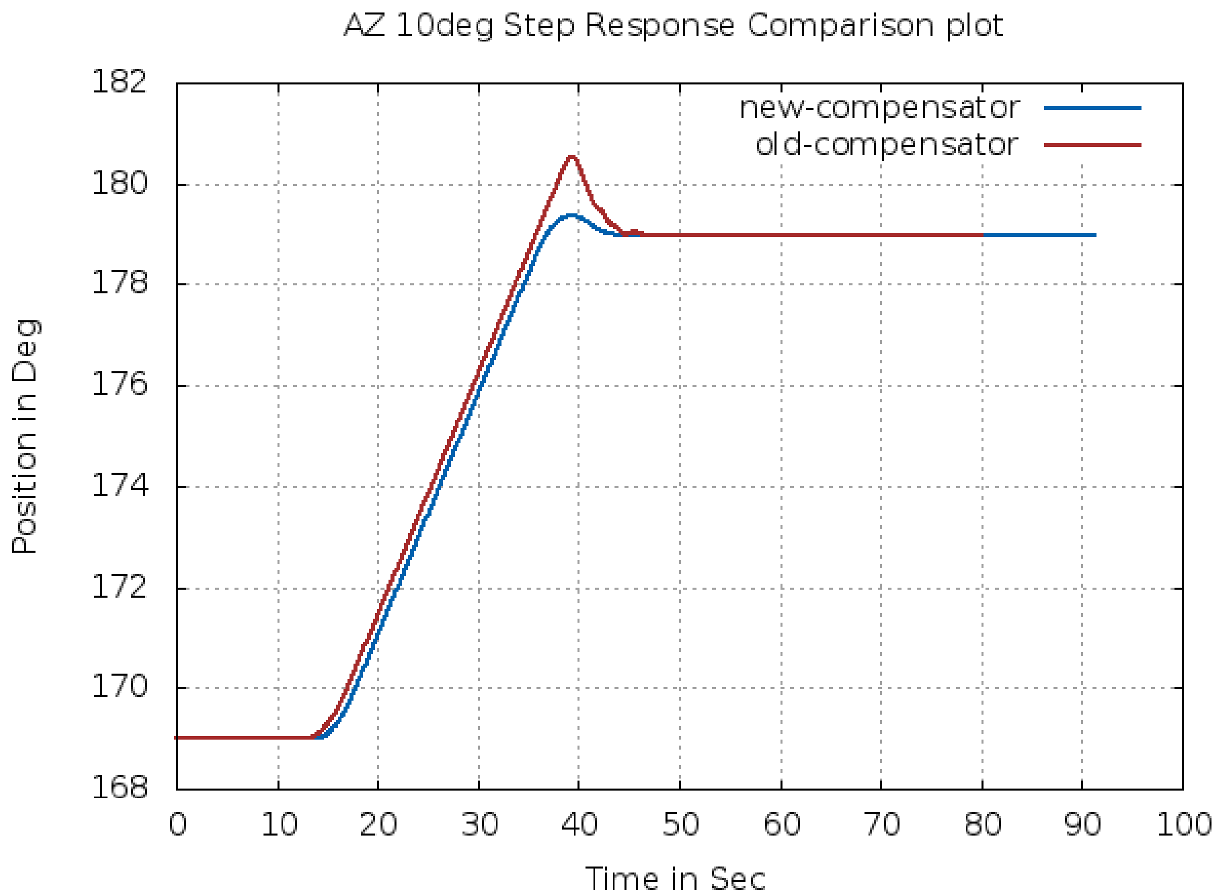
S.No	Description	New Type Compensator	Old Type Compensator
1	Delay Time (sec)	8.5	8.8
2	Rise Time (sec)	8.5	8.3
3	Settling Time (sec)	19.8	27.0
4	Peak Overshoot (%)	9.0097	20.9875
5	Peak Overshoot (arcmin)	27.0227	62.9480
6	Damping Factor		

Position Error and Speed Demand Comparison for five degree step





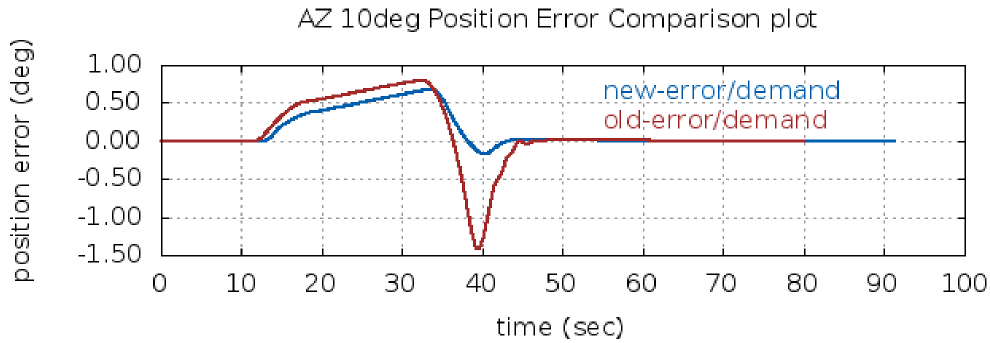
Case 3: Azimuth Ten Degree Step

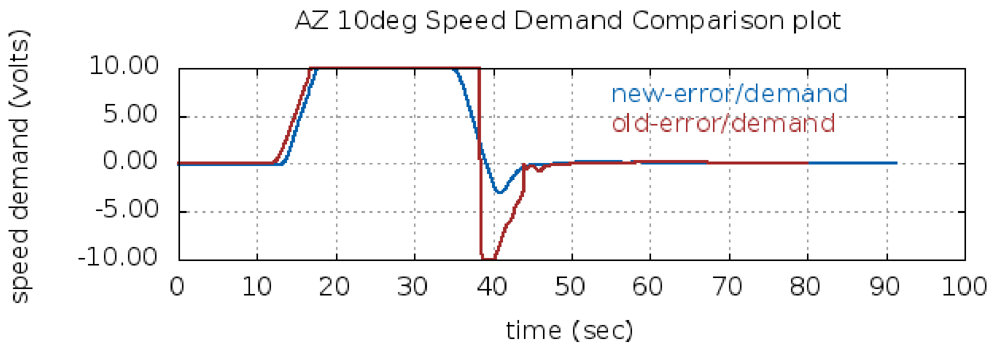


Time Domain Specification Comparison for ten degree step

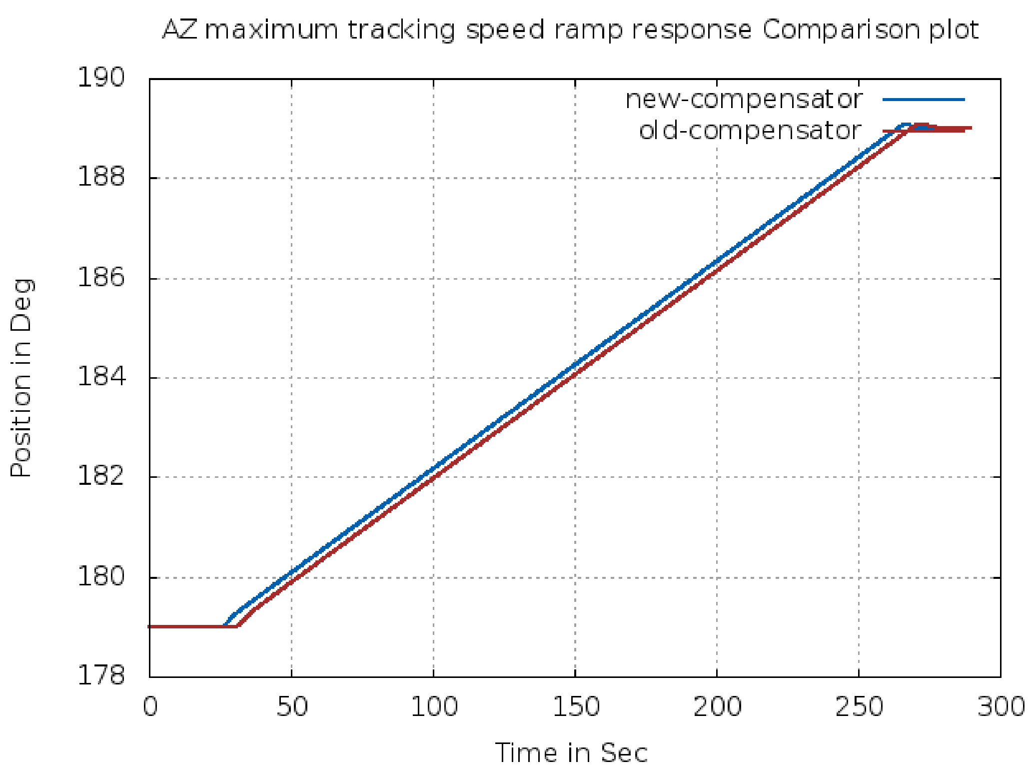
S.No	Description	New Type Compensator	Old Type Compensator
1	Delay Time (sec)	13.8	14.0
2	Rise Time (sec)	16.7	16.7
3	Settling Time (sec)	28.6	31.8
4	Peak Overshoot (%)	3.6004	15.4931
5	Peak Overshoot (arcmin)	21.6028	92.9590
6	Damping Factor		

Position Error and Speed Demand Comparison azimuth for ten degree step





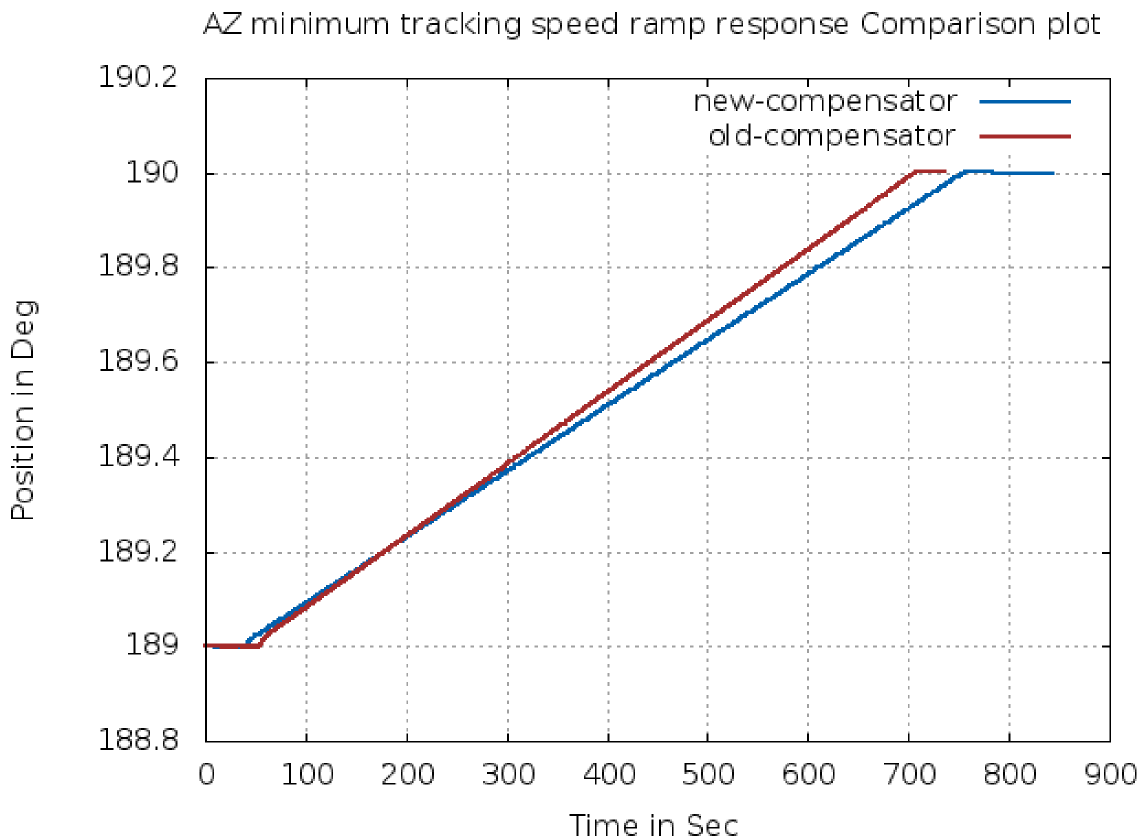
Case 4: Azimuth maximum tracking speed



Time Domain Specification Comparison for maximum tracking speed

S.No	Description	New Type Compensator	Old Type Compensator
1	Initial Maximum Error (arcsec)	237.5793	264.4409
2	RMS Error (arcsec)	31.92	42.64

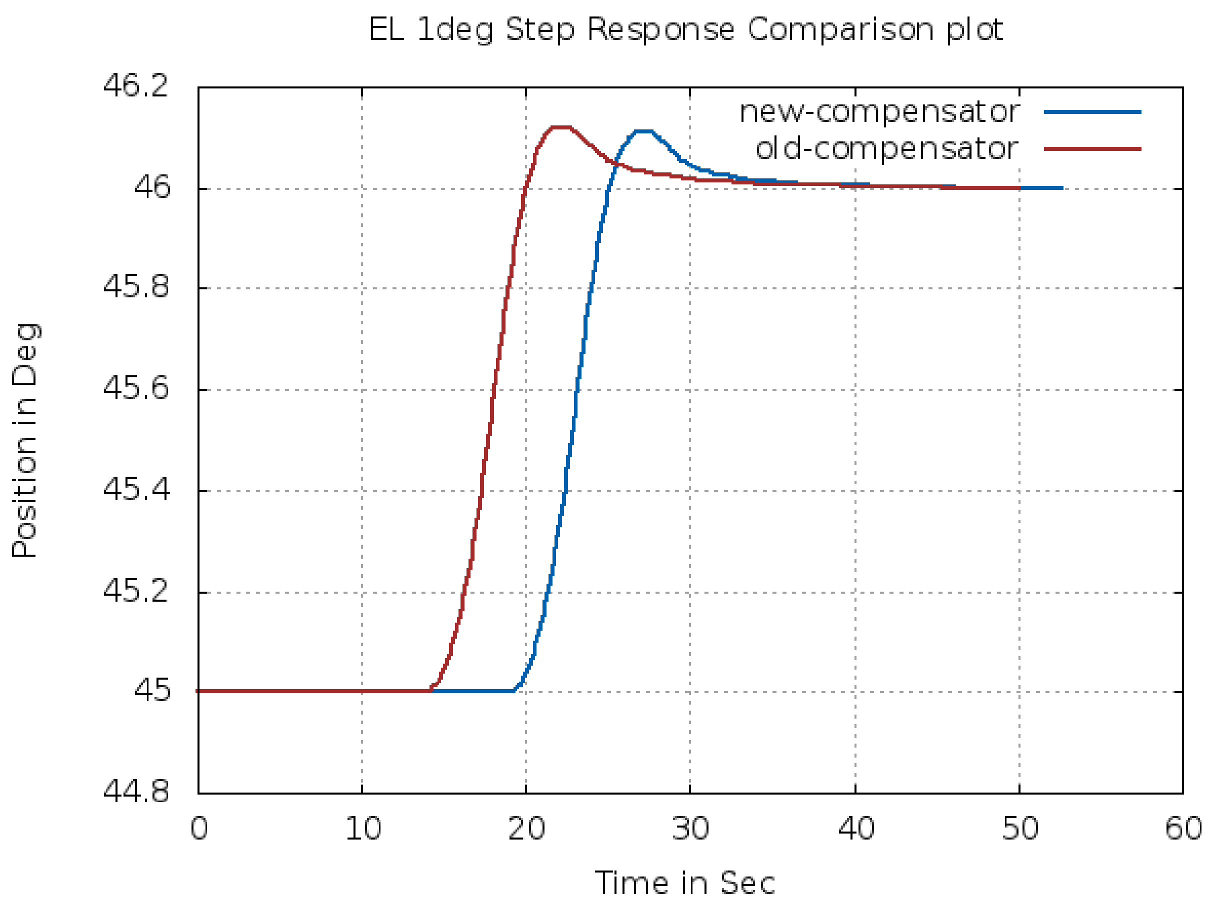
Case 5: Azimuth minimum tracking speed



Time Domain Specification Comparison for maximum tracking speed

S.No	Description	New Type Compensator	Old Type Compensator
1	Initial Maximum Error (arcsec)	31.4758	42.2424
2	RMS Error (arcsec)	4.27	5.00

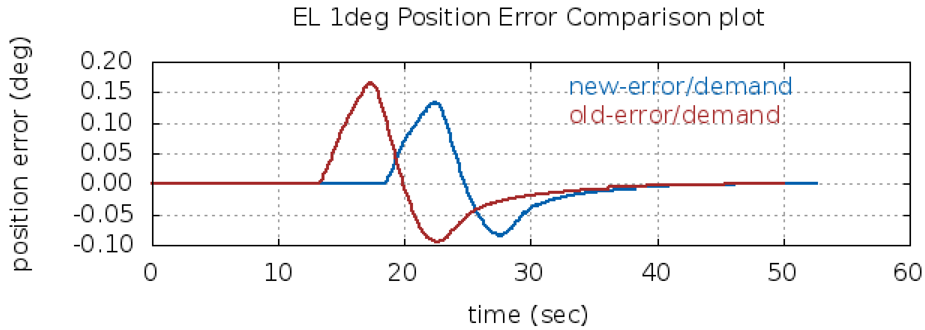
Case 6: Elevation One Degree Step input

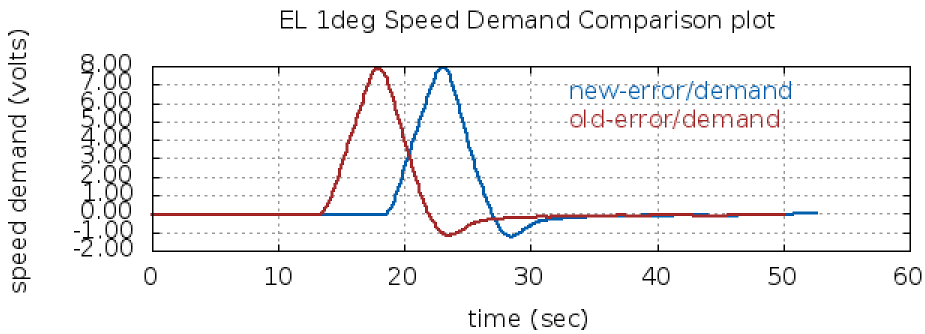


Time Domain Specification Comparison for EL one degree step

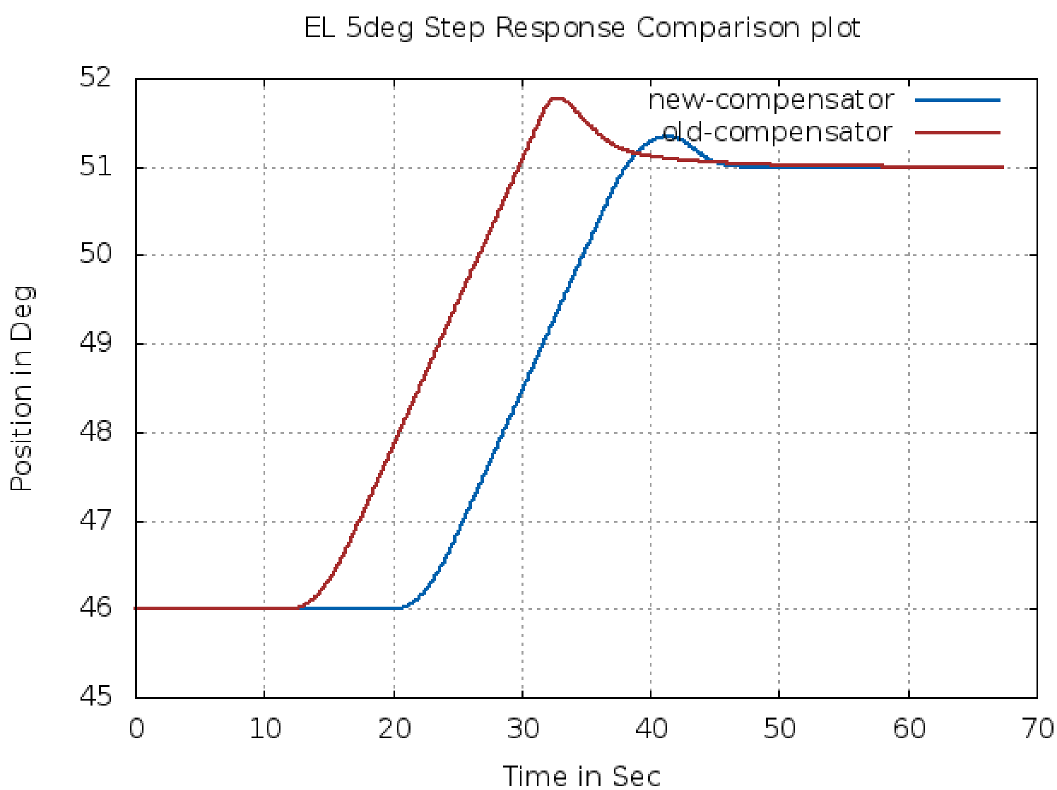
S.No	Description	New Type Compensator	Old Type Compensator
1	Delay Time (sec)	4.8	5.0
2	Rise Time (sec)	3.8	3.9
3	Peak Time (sec)	8.8	9.0
4	Settling Time (sec)	14.8	16.7
5	Peak Overshoot (%)	11.2366	12.0605
6	Peak Overshoot (arcmin)	6.7419	7.2363
7	Damping Factor	0.7837	0.7721

Position Error and Speed Demand Comparison for elevation one degree step





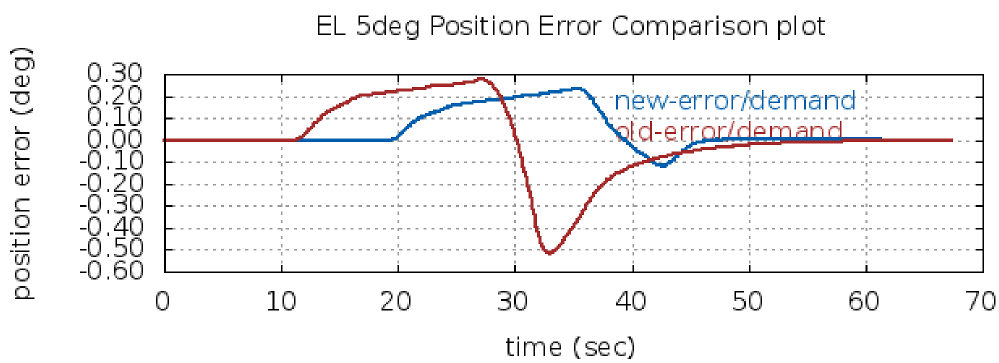
Case 7: Elevation five Degree Step input

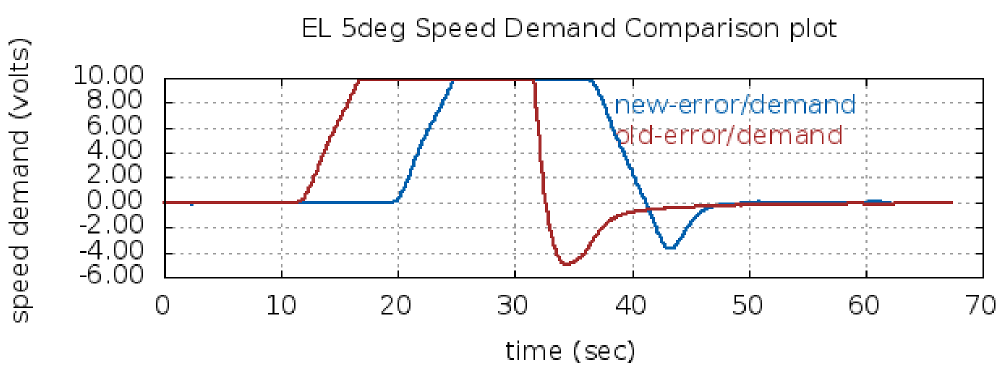


Time Domain Specification Comparison for EL five degree step

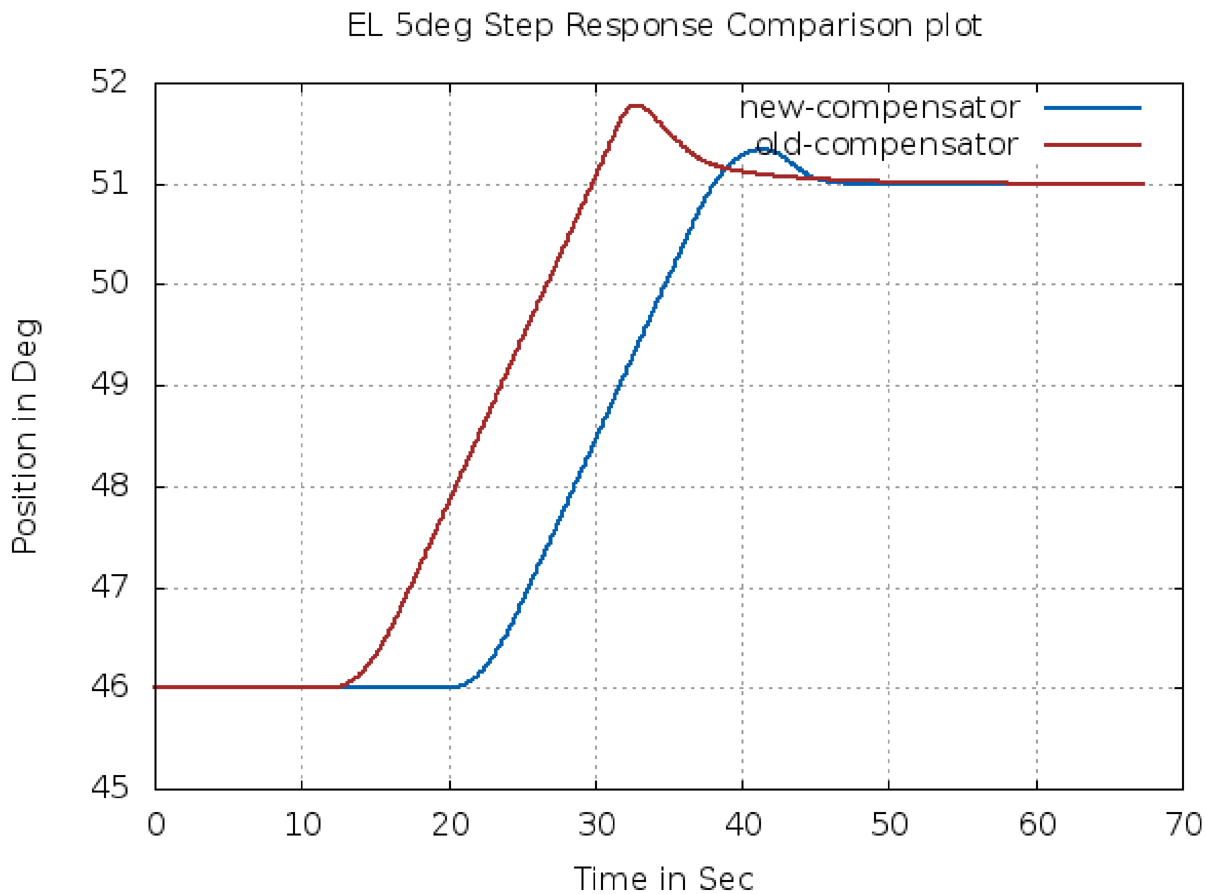
S.No	Description	New Type Compensator	Old Type Compensator
1	Delay Time (sec)	11.10	11.2
2	Rise Time (sec)	12.5	12.4
4	Settling Time (sec)	25.2	30.2
5	Peak Overshoot (%)	6.7270	15.5156
6	Peak Overshoot (arcmin)	20.1819	46.5491
7	Damping Factor		

Position Error and Speed Demand Comparison for EL five degree step





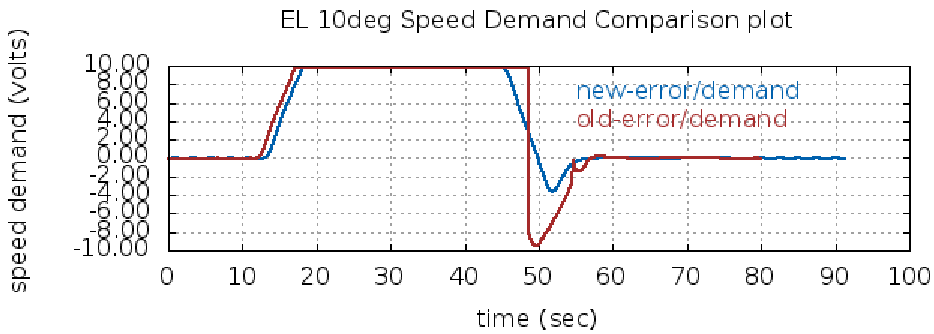
Case 8: Elevation ten degree step



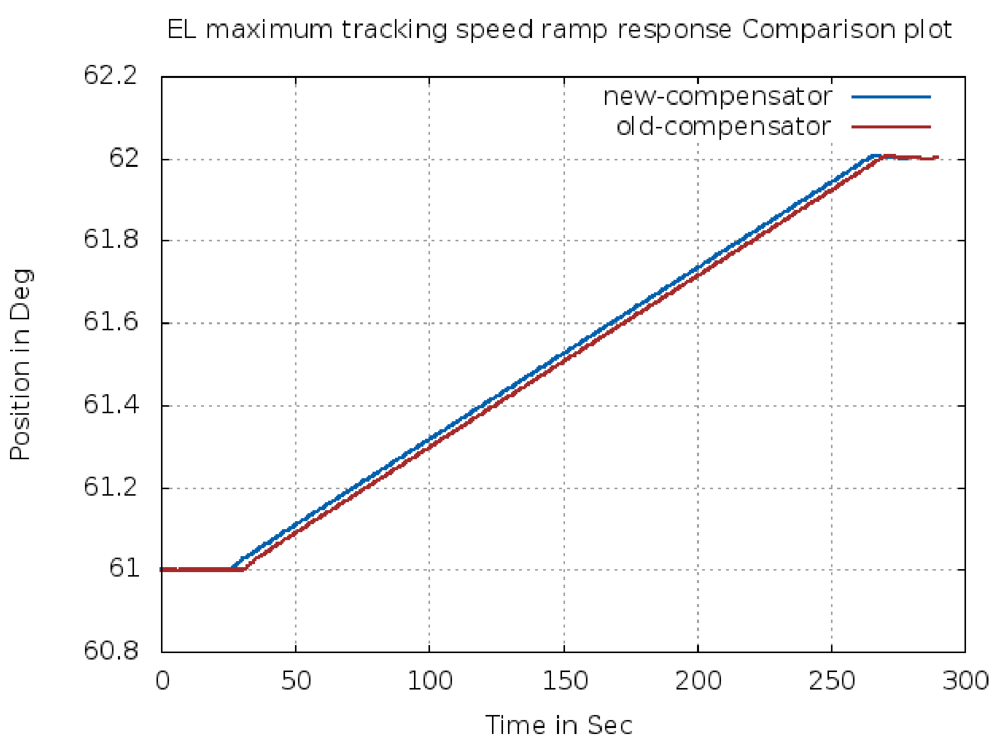
Time Domain Specification Comparison for EL five degree step

S.No	Description	New Type Compensator	Old Type Compensator
1	Delay Time (sec)	18.8	19.0
2	Rise Time (sec)	24.8	24.8
4	Settling Time (sec)	39.2	42.0
5	Peak Overshoot (%)	2.9268	10.5092
6	Peak Overshoot (arcmin)	17.5635	63.0469
7	Damping Factor		

Position Error and Speed Demand Comparison for EL ten degrees



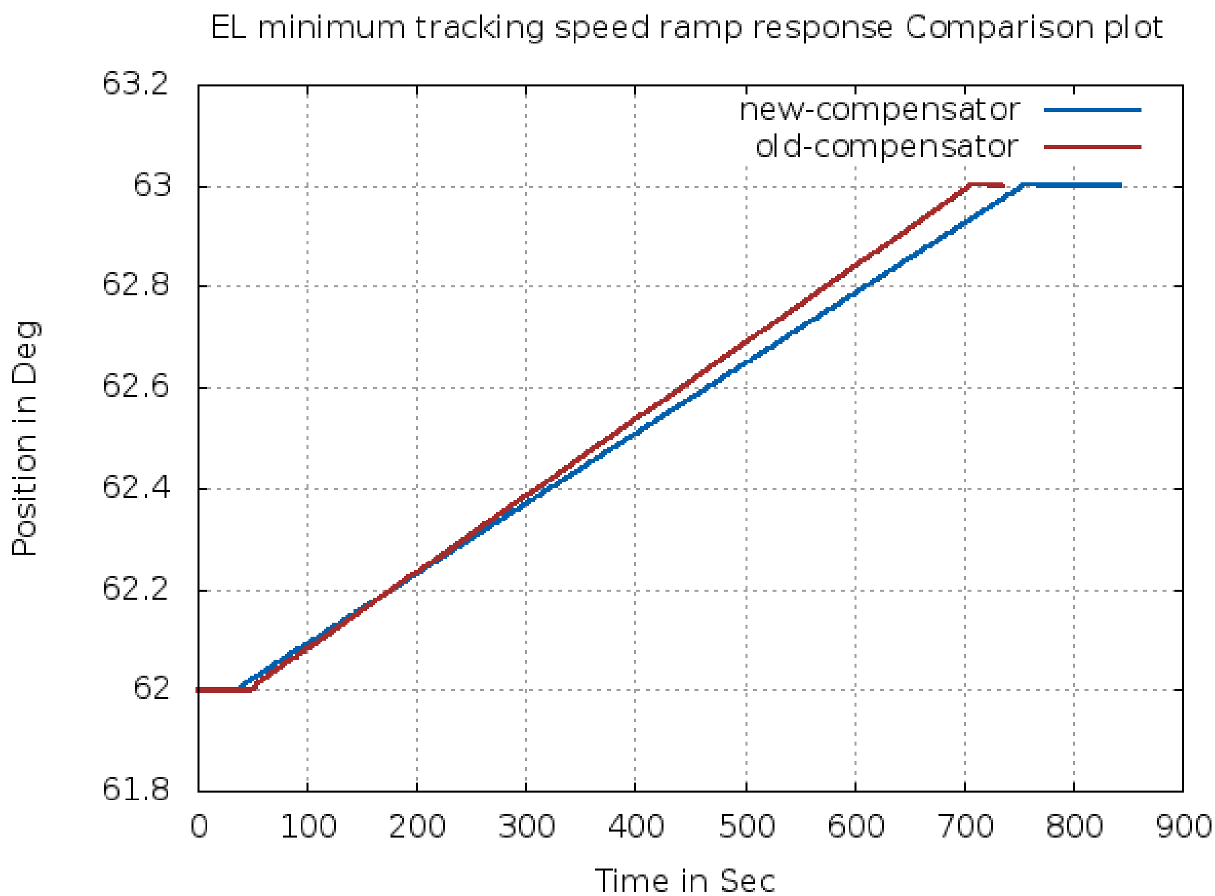
Case 9: Elevation Maximum Tracking Speed Comparison



Elevation maximum tracking speed tracking error comparison

S.No	Description	New Type Compensator	Old Type Compensator
1	Initial Maximum Error (arcsec)	27.9464	29.8141
2	RMS Error (arcsec)	4.27	4.63

Case 10: Elevation Minimum Tracking Speed Comparison



Elevation minimum tracking speed tracking error comparison

S.No	Description	New Type Compensator	Old Type Compensator
1	Initial Maximum Error (arcsec)	16.4932	18.4021
2	RMS Error (arcsec)	3.26	3.17

Conclusion

The modified compensator with removed position slew control provides improved performance when compared to old compensator (by comparison of time domain specification). As well as the problem of elevation down pre-limit hit can be resolved with new compensator, because of its lesser overshoot (<30arcmin) for all cases of step inputs.