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# Required Torque of Motor Brakes for Az and El Drives of GMRT Antennas

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## Summary

It is shown that the required value of the brake torque for each of the two Azimuth Motors (Az) is about 40 Nm and for each of the two Elevation Motors (El) is about 32 Nm. when 45 m antenna of GMRT is subjected to maximum survival wind speed of 133 kmph measured at 10m height. Although it is important that antennas are stowlocked in zenith position before the wind speed exceeds 85 kmph. the structural and mechanical systems have been designed as to be safe in any position of the antenna, because it is difficult to guarantee stowlocking under all circumstances. The purpose of this note is to bring to the attention of various engineers and users. the importance of ensuring that

*a)* that brakes are maintained so that the torque does not exceeds the values specified in this note (28 Nm for each of the El and Az motors or 56 Nm for the two Az or El motors combined), and

*b)* antennas are stow-locked whenever the one-minute wind exceeds 45-km per hour.

Motors purchased from M/s.Industrial Drive have a brake torque of only about 32 Nm, which was considered safe by TCE at the time of purchase. In order to ensure safety of the antennas against heavy wind loads. it is desirable to install dynamic braking to provide additional braking in case the antenna picks up appreciable speed during a heavy wind storm. Such a circuit should be installed at the earliest. In the mean time, all attempts should be made to stowlock the antennas well before the occurrence of a squall / thunderstorm which is generally accompanied with heavy winds.


## 1. Technical Considerations

1.1 The required brake torque, $T_b$, of the motors of the GMRT antennas is given by

$$T_b = \frac{1}{2}\left[\frac{T_l(v)}{N}\right]\eta \qquad (1)$$

Where $T_l$ = load torque at El. or Az. axis for wind speed, $v$; N = overall gear reduction of the drive, $\eta$ = overall efficiency of the gear train, and the factor $\frac{1}{2}$ arises because load torque is shared by two motors. Note that $\eta$ is in the numerator, because wind applies a torque at the output of the gear train that is resisted by the input brakes.

1.2 From the wind design values specified by the Indian Standards Institution for various zones of India, it is estimated that the maximum survival wind for a 50-year return period at the GMRT site is about 133 kmph for a 3 sec gust when measured at a 10 m height. During a storm, the wind may exceed 85 kmph for several minutes. It is necessary that brakes should supply sufficient holding torque so that antennas do not rotate in such heavy winds in case they do not get stowlocked.

## 1.3 Gear-drive Ratios

For the GMRT antennas, the overall gear reduction ratio is given by

$$N(Az) = 18,000 \quad --- \quad approx.$$

$$N(El) = 25,000 \quad --- \quad approx.$$

## 1.4 Gear-train Efficiency

In their design report for Mechanical System, TCE had assumed overall efficiency of the gear box and the slew-ring for the Az axis, and the gear box and the pin sector for the El axis to be about 0.63 and 0.6 respectively. However, the measured efficiency by Swarup *et al* (1993) and Joshi *et al* (1994) is found to be about 0.78 ± 0.02 for both cases.

## 1.5 Azimuth Torques

The maximum torque on the Azimuth axis of the antenna for $v$=133 kmph, as calculated by TCE, is given by

$$T_l(133) = 186,000 \text{ kgm} \qquad (Az\ axis)$$

This torque is applied by the wind on the azimuth axis of the antenna when the dish is pointed close to the horizon and wind direction is sideways to the dish, i.e., perpendicular to the face of the dish. The Azimuth torque is about 10 percent of the above value when the dish is facing zenith and not zero because the elevation axis of the GMRT antennas is offset by about 0.6m from the vertical Az axis. The torque for velocity $v$ is given by

Using equations (1) and (2), we have given in Table 1 the required brake torque for each of the two Az motors for various wind speeds. It may be noted that we have ignored input friction torque of the gear box which has been measured by M/s.Roxroth and also estimated at GMRT to be only about 1 Nm.

$$Az: \qquad T_b(v) = \left(\frac{v}{133}\right)^2 \times \frac{186,000}{18,000} \times \frac{9.81}{2} \times 0.78\mathrm{Nm}$$

$$= 2.23 \times 10^{-3} v^2 Nm$$

The values of Az torque at various wind speed is tabulated below (Table 1)

Table 1 : Required value of Brake torque for each of the Az motor

| Sr. | $v$ (kmph) | $T_b$ (kgm) | $T_b$ (Nm) |
|---|---|---|---|
| 1 | 20 | 0.09 | 0.9 |
| 2 | 40 | 0.36 | 3.6 |
| 3 | 60 | 0.82 | 8.0 |
| 4 | 80 | 1.46 | 14.3 |
| 5 | 100 | 2.28 | 22.3 |
| 6 | 133 | 4.03 | 39.5 |

## 1.6 Elevation Torques

The maximum wind load torque gets applied on the Elevation axis when the dish is facing zenith and wind direction is perpendicular to the El axis. Torque on the antenna and required brake torque for each motor are given by

$$T_l(133) = 206.000 \quad \mathrm{kg.m} \qquad (3)$$

$$El: \qquad T_b(v) = \left(\frac{v}{133}\right)^2 \times \frac{206,000}{25,000} \times \frac{9.81}{2} \times 0.78 \quad \mathrm{Nm} = 1.78 \times 10^{-3} v^2 Nm$$

The values of El torque at various wind speeds are tabulated below (Table 2)

Table 2: Required values of $T_b$ for various values of $v$ for El motors.

| Sr. | $v$ (kmph) | $T_b$ (kgm) | $T_b$ (Nm) |
|---|---|---|---|
| 1 | 20 | 0.07 | 0.7 |
| 2 | 40 | 0.28 | 2.8 |
| 3 | 60 | 0.65 | 6.4 |
| 4 | 80 | 1.16 | 11.4 |
| 5 | 100 | 1.81 | 17.8 |
| 6 | 133 | 3.21 | 31.5 |

## 2. Discussions and Conclusions

It is seen from Table 1 and Table 2 that the required value of the brake torque for Az and El motors is about 40 and 32 Nm for the survival wind velocity, $v$ = 133 kmph respectively. On the other hand the motors purchased from M/s.Industrial Drive, U.S.A. provide brake torque of only 32 Nm by specifications. The actual values measured recently on some of the installed motors are given in Table 3. Originally TCE had specified a required torque of 40 Nm but M/s.Industrial Drive could not provide the same because of our requirement of a manual drive at the input of the motor. The manual drive was considered advantageous for stowlocking the antennas manually for such a case when heavy wind is expected but the electric drive might not be available due to any system failures. For the manual drive. M/s.Industrial Drive required brake model to be placed at the input. which restricted the achievable brake torque for their motor.

Since TCE, estimated the overall efficiency of the gear drives to be about 0.6, a value of 32 Nm offered by M/s.Industrial Drive was considered satisfactory at that time. However. since the measured efficiency of the gear drives is about 0.78. we require a higher value of torque than available for the motors purchased. particularly for the Az motors.

This problem has been discussed with the Servo group. It was suggested a that dynamic braking may be planned in case of heavy winds by switching ON a resistor in parallel to the motor windings so as to apply regenerative braking and thus limit the resulting velocity of the antenna, when the antenna starts rotating with wind due to insufficient brake torque. However, a note needs to be written regarding the feasibility of the scheme. This must be expedited. Also. the scheme needs to be demonstrated in the servo laboratory in a suitable way.

It may be noted that preliminary measurements made during May-June 1994 indicated that the actual measured torque during heavy winds on the elevation axis of the antennas may be only about 70-80 per cent of that calculated by TCE. This could be due to somewhat higher values of the aero-dynamic co-efficients assumed by TCE than actually applicable. Sufficinet information was not available in the literature for the sparse wire mesh and back-structure of the GMRT dishes. Wind tunnel measurements were made for the wire mesh of by NAL but had relatively large errors because the wire mesh is rather sparse. Wind tunnel measurements of the back-up structure by the Roorkee University did indicate somewhat lower torques than calculated by TEC. It is planned to estimate wind torques on GMRT antennas again during windy days in May-July 1996.

In case of inadequate brakes of El motors, antennas can get driven by the heavy winds causing severe structural damage. For the case of Az motors, all the numerous electrical and electronics cables can get damaged if the wind drives the antenne beyond ±270 degrees.

# CONCLUSION

To conclude, a view should not be taken that we could accept smaller values of the brake torque since antennas are stow- locked in heavy winds. It should be noted that it is not possible to guarantee stowlocking due to two reasons :

(a) Unforeseen failure of one of the drive components in the servo system.

(b) It is known that winds may suddenly rise from about 20 or 30 kmph to more than 100 kmph within 5 to 10 minutes during a severe thunderstorm squall in the Pune region.

Therefore, we should ensure that the brake torques are not below about 28 Nm for each of the four motors particularly during April to July each year. The defective assembly MUST be repaired promptly. We should also import some more brake assemblies. Also, priority should be given for developing automatic stowlocking and dynamic braking over the next few months. In the mean time, we should not operate the antennas on very windy days.

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Table 3 BRAKE TORQUE

Observed in Central Square Antennae

| Ant | Azimuth Motor Brake Torque in N.m. | | Elevation Motor Brake torque in N.m | |
|---|---|---|---|---|
| | L.H | R.H | L.H | R.H |
| C0 | 30 | 32 | 28 | 30 |
| C1 | 30 | 32 | 33 | 28 |
| C2 | 32 | 28 | 28 | 28 |
| C3 | 32 | 38 | 28 | 28 |
| C4 | 32 | 38 | 34 | 30 |
| C5 | 32 | 34 | 32 | 30 |
| C6 | 32 | 34 | 32 | 30 |
| C8 | 32 | 28 | 24 | 32 |
| C9 | 32 | 38 | 26 | 22 |
| C10 | 30 | 32 | 30 | 34 |
| C11 | 32 | 34 | 28 | 30 |
| C12 | 30 | 32 | 25 | 30 |
| C13 | 36 | 32 | 34 | 28 |
| C14 | 32 | 30 | 30 | 28 |
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