# APPENDIX I

## Typical Fault Reports of Indian Railways

### REPORT NO: 1

**SOUTHERN RAILWAY**

Divisional Office,  
Electrical Branch,  
Trivandrum-695 014  
Date - 10.12.2001

Dear Sirs

Sub: Alternator failures.  
Ref: This office letter of even no. dated 23.11.2001

Please refer to this office letter cited above, where in two cases of alternator failures, which had occurred within one month in Trivandrum division had been reported. Further to the above, two more cases of alternator failures have occurred, leading to a total of four cases of alternator failures within just one month. Details of all the above mentioned four cases of alternator failures are furnished below for your ready reference.

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Train No.</th>
<th>Coach No.</th>
<th>POH</th>
<th>Date of failure</th>
<th>Make of Alternator</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6327</td>
<td>SR SLR 7674</td>
<td>PWP</td>
<td>27.3.01</td>
<td>4.5 KW S.No 990931945</td>
<td>Alternator shaft broken near pulley, bearing end and pulley missing. Replaced with new alternator</td>
</tr>
<tr>
<td>2</td>
<td>6345</td>
<td>SR CN 95368</td>
<td>PWP</td>
<td>23.3.01</td>
<td>4.5 KW/</td>
<td>Alternator shaft broken near pulley bearing end and pulley missing. Replaced with new alternator</td>
</tr>
<tr>
<td>3</td>
<td>6308</td>
<td>SR GS 96423</td>
<td>PWP</td>
<td>23.2.00</td>
<td>45 KW/</td>
<td>Alternator shaft broken near alternator frame and alternator pulley missing. (No marks of external hit found on the underframe). All the four V-belts missing</td>
</tr>
<tr>
<td>4</td>
<td>6345</td>
<td>SR CN 96379</td>
<td>PWP</td>
<td>8.8.01</td>
<td>4.5 KW/</td>
<td>Alternator pulley missing. Replaced with new alternator</td>
</tr>
</tbody>
</table>

Shaft breakages leading to pulley droppings are serious type alternator failures. This type of repeated failures are not acceptable to Rlys. which may even cause derailments and accidents.

Therefore, immediate investigation is needed for finding out the cause for these failure and to take remedial actions for arrests these type failures.

This has reference to Telenthonic discussion had on the subject by us with IM of yours.

CC: CESEMAS - for kind information  
CEW/PER - for kind information.

Electrical Branch,  
Trivandrum.
**REPORT NO: 2**

TVC/TLD/8

Office of the Sr SEE/TLD/TVC

21-12-2001

Sub: Alternator failure – Rotor shaft broken.
Ref: Lt No. V/e. 227/1/TL Mtg.

As directed by Sr.DEE/TVC, following defective shaft broken alternators that are released from this depot coaches sending through your representative for repairs and early return please.

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Coach No</th>
<th>Released/Date of failure</th>
<th>Make of Alternator/SL No</th>
<th>Nature of Defect</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SLR 7674</td>
<td>27/10/2001</td>
<td>990931945</td>
<td>Shaft broken</td>
</tr>
<tr>
<td>2</td>
<td>CN 96368</td>
<td>06/11/2001</td>
<td>97/349</td>
<td>Shaft broken</td>
</tr>
<tr>
<td>3</td>
<td>CN 96378</td>
<td>08/12/2001</td>
<td>9112318404</td>
<td>Shaft broken</td>
</tr>
<tr>
<td>4</td>
<td>CN 93214</td>
<td>15/12/2001</td>
<td>94/335</td>
<td>Shaft broken</td>
</tr>
<tr>
<td>5</td>
<td>CZ 92622</td>
<td>19/12/2001</td>
<td>9011316670</td>
<td>Shaft broken</td>
</tr>
<tr>
<td>6</td>
<td>CN 85219</td>
<td>22/06/2001</td>
<td>9511321144</td>
<td>Shaft broken</td>
</tr>
</tbody>
</table>

TLD/TLD of 29/5/02

Forwarded to Sr.DEE/TVC

Under this account one alternator bearing Sl.No. 990931945 were only received: now waiting for balance items. Kindly do needful.
APPENDIX II

NO LOAD GENERATED VOLTAGE-THEORETICAL ANALYSIS

In the 4.5kW three phase train-lighting alternator considered, the theoretical analysis for obtaining the generated no load voltage is performed as follows:

STEP 1:

Let at any time t, the rotor position is as shown in figure 5.1. Coil 1 of R Phase lie in stator slots 1 and 4.

Slot angle = 7.5 Mechanical Degrees = 60 Electrical Degrees

Coil span = 180 Electrical Degrees

As a rotor tooth enters this coil span and leaves it, the flux linkage in Coil 1 changes as shown in figure 5.2.

STEP 2:

The flux linkage \( \phi \), of one armature coil, can be calculated based on the position of the rotor tooth, as

\[
\phi = T \frac{\mu_0 V_0 r l \theta}{g} \quad (i)
\]

where \( T \) is the number of turns per armature coil, \( \mu_0 \) the permeability of free space, \( V_0 \) the ampere turns acting across each air gap, \( r \) the radius of the rotor, \( l \) the effective axial length of the rotor, \( \theta \) the angular position of the rotor tooth in mechanical radians and \( g \) the air gap length.
For the machine considered,

- Number of turns per AC armature coil \( T \) = 8
- Number of turns per DC Excitation coil = 200
- Value of DC Excitation Current = 4A
- Number of DC Excitation coils = 2
- Ampere turns acting across each air gap \( V_0 \) = 800AT
- The radius of the rotor \( r \) = 8.69cm
- Length of air gap \( g \) = 0.45mm
- Effective axial length of the rotor \( l \) = 0.3metres
- Span of one rotor tooth, \( \theta \) = 60° Mechanical (128° Electrical)

Maximum flux linkage in Coil 1

\[
\frac{T \mu_0 V_0 r l}{g} \times 60^\circ \times \frac{\pi}{180^\circ}
\]

Calculated value of Maximum flux linkage in Coil 1 = 0.13 Weber turns

**STEP 3:**

At a speed of 1500 rpm, time required for one revolution of the rotor is 0.04 seconds, so that the time required for the rotor to cover 360 electrical degrees is calculated as 0.005 seconds. The time to cover an electrical angle of 128° will then be equal to 1.78 \times 10^{-3} seconds. One complete cycle of flux linkage pattern consist of four regions, Region I from 0° to 128°, Region II from 128° to 180°, Region III from 180° to 308° and Region IV from 308° to 360°, as shown in figure 5.2.
Induced voltage in Region I = $-\frac{d\phi}{dt} = -\frac{(0.13 - 0)}{1.78 \times 10^{-3}} = 73.03$ volts

Induced voltage in Region II = 0 (since there is no change in flux linkage)

Induced voltage in Region III = + 73.03 volts

Induced voltage in Region IV = 0 (since there is no change in flux linkage)

The induced voltage in Coil 2 (lying in slots 7 to 10) lags or leads the induced voltage in Coil 1 (lying in slots 1 to 4) by 360 electrical degrees. Similarly, the induced voltage in Coil 3 (lying in slots 11 to 13) lags or leads the induced voltage in Coil 1 by 720 electrical degrees. The no load induced voltage in one coil and the resultant voltage in three coils at 1500 rpm are shown in figures 5.3 and 5.4 respectively.

STEP 4:

The Fourier series of the voltage induced in coils may be expressed as,

$$ v(\theta) = \frac{a_0}{2} + \sum_{n=1}^{\infty} (a_n \cos n\theta + b_n \sin n\theta) $$

where,

$$ a_0 = \frac{1}{\pi} \int_{0}^{2\pi} v(\theta) d\theta = 0 $$

$$ a_n = \frac{1}{\pi} \int_{0}^{2\pi} v(\theta) \cos n\theta d\theta $$

$$ b_n = \frac{1}{\pi} \int_{0}^{2\pi} v(\theta) \sin n\theta d\theta $$

For $n=1,2$ and 3, using the above equations, $a_1, a_2, a_3, b_1, b_2$ and $b_3$ are calculated and tabulated in TABLE 5.2. The 5th harmonic is minimal because of
the skew of $72^0$ electrical. The final expression for the voltage is also provided in TABLE 5.2. Since the length of iron path is extremely large compared to the air gap, a correction is to be applied to the available mmf at the air gap, as iron was found to consume about 33% of the mmf.

**STEP 5:**

To analyse the rotor skew in two-dimension, a multi-slice model is used in which skewed rotor slots are modelled by dividing the machine into short axial sections, each of which is rotated by a small amount to simulate rotor skew. The magnetic field is then solved for each of these regions, from which all other important quantities are obtained. The entire axial length of 30 cm was divided into 5 equal divisions of 6 cm each. In each of these divisions, the magnitude of the coil induced voltage will be one fifth of the total whereas, the fundamental component and the third harmonic component, lags by one fifth of the skew angle and three fifth of the skew angle, respectively from the corresponding components of voltage in the previous section. The expressions of the induced voltages in the five sections of the rotor are tabulated in TABLE 5.4.