CHAPTER 2

SOLID ROTOR ALTERNATOR

2.1 INTRODUCTION

Any heteropolar rotating machine is inherently an alternator, in the sense that the emf induced in each armature conductor is an alternating emf, with an exception to the DC generator where the field system is stationary in space and the distribution of potential around the armature. In other words, an alternator is an AC generator consisting of a coil of wire rotating between the poles of a magnet. The two ends of the coil do not need to be connected to a commutator and are instead, connected to a pair of sliprings on each of which a brush is placed to collect the current. In ideal case the induced emf always obeys a sine law of the type

\[ e = E_m \sin \omega t \]

an increase in the number of turns results in an increase in the induced voltage. In case of three phase alternator, the corresponding conductors will be always situated two-thirds of a pole pitch distant from each other, irrespective of the total number of poles. From a theoretical point of view it is immaterial whether the armature rotates between the poles or the poles rotate inside a stationary armature. But rotating field type is standard practice owing to several inherent advantages.
1. A higher peripheral speed may be employed, as it is easier to make a sound mechanical job of the poles and pole windings than of the armature winding with its end connections.

2. Since the armature is on the outside, there is no room for its winding where it is preferable to have HT winding stationary.

3. A three phase alternator with a rotating armature requires three slip rings and a two phase machine requires four where as only two slip rings are necessary in case of rotating field. With rotating armature the slip rings must be insulated for the full armature voltage where in case of rotating field, it is not required.

The stationary element is called stator and the rotating element the rotor. Problems in connection with the design and operation of turbo-type generators in certain special cases indicates that the characteristics of the SRA are worthy of consideration .Such generators are not new, but relatively few have been commissioned and these are of very large output. In order to study the behavior of such SRA, a prototype has been designed and assembled. Initially a program in C has been developed to accommodate design of any such machines which is shown in appendix A.

2.2 SRA DESIGN PROCEDURE

2.2.1 Stator Core

The stator core is built up with segmental laminations in order to reduce eddy current loss. Cold rolled sheet steel has the directional
properties that give a low specific iron loss when the direction of the flux is parallel to the direction of rolling but a substantial higher iron loss when the direction of the flux is across the direction of rolling.

The modern synchronous machines use non directional cold rolled steel which has electrical characteristics identical to hot rolled steel but has much improved mechanical characteristics like uniformity of thickness of laminations, higher fatigue strength and lower clamping.

The stator laminations are either punched as a complete circle or in the form of segments. The insulated laminations are assembled in the stator frame. Winding is to be done on the obtained stator.

2.2.2 Stator Winding

The stator winding of turbo alternator is a double layer winding as shown in Fig.2.1. A generator designed for high voltage no doubt requires a high level of slot insulation but permits the use of smaller sized conductors with the ensuring advantage of lesser number of parallel circuits, smaller pulsation forces between conductors lesser conductors subdivision and ease in coil formation and insulation. The generation voltages normally used is 15kV for 100-200MW machine and 20-25kV for larger machine [17].
2.2.3 Rotor Core

The rotor is generally made up of chromium nickel steel or chromium molybdenum steel. The rotor consists of a core and shaft generally forged in one piece except in very large sizes. Generally, two thirds of rotor is wound and the rest one third is left without slots. This unwound portion forms the so called large tooth through which the main part of generator fluxes passes. Manganese bronze or steel wedge is driven into the mouth of each slot for the purpose of keeping the winding in place. At the bottom of each slot a ventilating duct or a sub slot may be used for providing a thorough passage for cooling air. The end conductors(overhang) of the field winding must be rigidly supported by end bells because of the large centrifugal forces due to high speed of rotation and also because of still larger force to which the field winding is subjected in case of a sudden short circuit of armature. This is because under short circuit conditions, not only large transient currents are produced in the armature but also there
are transient unidirectional voltages and currents, which are many times the normal values.

### 2.2.4 Rotor Windings

The windings used in synchronous machines may be single layer or double layered type as shown in Fig.2.2. Machines having large values of flux per pole have small number of turns per phase and therefore a double layer bar winding is used for them. However, high voltage machines with small values of flux per pole have a large number of turns per phase. Therefore, multi-turn coils are used for such machines. For machines using multi-turn coils choice lies in between double layer lap winding and single layer concentric winding. The former is dropped into open type of slots while with the later, hairpin coils are pushed through semi-enclosed slots.

![Windings of Solid rotor](image)

Fig.2.2: Windings of Solid rotor
2.3 CONSTRUCTIONAL FEATURES OF OTHER PARTS

2.3.1 Bearings

Bearings play an important role in the operation of synchronous machines. In the case of turbo-alternators having very low ratings, plain-bearings with rings for oil circulation are used and different parts of alternator are shown in Fig 2.3. The bearings must be oil-tight as any leakage of oil from the bearing has the possibility of entering the machine, spoiling its insulation and resulting in a shut down.

![Different parts of generator](image)

1. Generator shaft  
2. Rolling bearings  
3. Rotor  
4. Rotor aluminium bar  
5. Rotor aluminium ring  
6. Stator  
7. Coil  
8. Stator plates  
9. Coil heads  
10. Ventilator  
11. Connection box

Fig.2.3: Different parts of generator

2.3.2 Sliprings and the Brushes

The slip rings are required to supply excitation to the field winding. The slip rings are made of steel and are shrunk over cast iron sleeve with mica as insulation between the two as shown in
Fig.2.4. In case of a generator with mounted exciter machines, slip
rings are generally provided above the generator. The brushes are
normally electro graphite brushes.

![Fig.2.4: Brushes and sliprings](image)

**STATOR DESIGN DATA SHEET**

**NAME PLATE DETAILS**

Phase : 3  
Frequency : 50 Hz  
Voltage : 400 V  
Current : 7.2A  
Power : 4.9 kVA  
Speed : 1500 RPM  
Power factor : 0.8 lagging  
Rating : Continuous
### MAIN DIMENSIONS

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Value</th>
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<tbody>
<tr>
<td>Outer diameter</td>
<td>168 mm</td>
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<tr>
<td>Inner diameter</td>
<td>108 mm</td>
</tr>
<tr>
<td>Core length</td>
<td>110 mm</td>
</tr>
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</table>

### WINDING DETAILS

<table>
<thead>
<tr>
<th>Detail</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of slots</td>
<td>24</td>
</tr>
<tr>
<td>No. of coils</td>
<td>2</td>
</tr>
<tr>
<td>SWG</td>
<td>22 + 23 (In parallel)</td>
</tr>
<tr>
<td>Pitch</td>
<td>1-6</td>
</tr>
<tr>
<td>Connection</td>
<td>Star</td>
</tr>
<tr>
<td>Insulation</td>
<td>Class F (Nomex paper)</td>
</tr>
</tbody>
</table>

### ROTOR DESIGN DATA SHEET

<table>
<thead>
<tr>
<th>Detail</th>
<th>Value</th>
</tr>
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<tr>
<td>Voltage</td>
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</tr>
<tr>
<td>Current</td>
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<tr>
<td>Length</td>
<td>110mm</td>
</tr>
<tr>
<td>Diameter</td>
<td>106mm</td>
</tr>
<tr>
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</tr>
<tr>
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<tr>
<td>Slot width</td>
<td>5mm</td>
</tr>
<tr>
<td>Slot depth</td>
<td>23mm</td>
</tr>
<tr>
<td>No. of turns</td>
<td>400</td>
</tr>
<tr>
<td>Coil groups</td>
<td>2</td>
</tr>
</tbody>
</table>
**SWG** : 19 + 20 (in parallel)

**Pitch** : 1-5

**Connection** : lap

**Insulation** : Class F (Nomex paper)

**Exciter rating** : 740 W

**Current** : 5 A

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**Fig.2.5: Waveform of SRA output voltage before redesigning**

### 2.4 REDESIGNING OF SRA

The existing SRA is redesigned as the output of the waveform of alternator is with much of harmonics which is as shown in Fig.2.5

Two probable avenues were found suitable in getting the output waveform closer to sinusoidal. They are:

- a) Increasing the number of slots of rotor such that slot harmonics will be reduced.
b) Increasing the length of air gap (By reducing the diameter of rotor)

Increasing the length of the air gap is achieved by reducing the diameter of the rotor. The SRA is decoupled from the DC motor as shown in Fig. 2.6, to remove the rotor from the stator.

![Fig.2.6 Decoupled alternator](image)

The alternator is completely dismantled and the different parts of the alternator are placed as shown in Fig.2.7. Before starting the machining process, as a precautionary measure varnish is poured on the rotor as shown in Fig.2.8. In order to avoid the spilling of the
rotor lubricant on to the windings, the rotor is made ready to dry up as shown in Fig.2.9.

Fig.2.8: Rotor immersed in varnish

Fig.2.9: Drying up the varnished rotor
The varnished rotor is placed in the oven as shown in Fig.2.10 to make the varnish hard. The rotor is subjected to heat for 6 hrs, the varnish will fill up the gaps in windings so that lubricant cannot enter into the windings. Due to limitation of wedges height, the cooled rotor (after taking out from oven) is machined to reduce the diameter by 1 mm only.

To drive out the dust particles present on the surface of the chamfered rotor which is shown in Fig.2.11 the cleaning process is carried out by a blower and all the measurements are taken i.e, length as shown in
Fig.2.14, diameter as shown in figure Fig.2.12, weight as shown in figure Fig.2.13. The specifications of the redesigned rotor are same as the design data sheet mentioned in page 17 except the diameter of the rotor as 105 mm.

2.5 EFFECT OF CHANGE OF DIAMETER OF ROTOR

1. Before redesigning of solid rotor alternator, its diameter was 106 mm. With that diameter the SRA was able to give 400 V (L-L) at the output terminals, but with more distorted sinusoidal waveform (which is evident from Fig 2.6)

2. After redesigning, the diameter of the rotor is reduced by 1 mm i.e. the diameter is 105 mm. With this diameter, though the output voltage of SRA is reduced at the same time the reduction in the diameter of the rotor also resulted in the reduction of harmonics i.e. better sinusoidal waveform than the previous case which is evident from Fig. 2.19
Fig. 2.13: Rotor weight after machining 9.22kg

Fig. 2.14: Length of the rotor 110 mm

Now the rotor is insulated with a solution ‘RED INSULATION’ as shown in Fig. 2.15 which protects the rotor from rusting and used especially in industry only.
Fig. 2.15: Rotor insulated with RED INSULATION

The machined rotor is inserted in the stator as shown in Fig. 2.16 and the end shields are fixed at both the ends as shown in Fig 2.17

Fig. 2.16: Rotor inserted Stator
The redesigned alternator is coupled to the DC motor as shown in Fig. 2.18. Now the experiments can be carried out on the newly redesigned alternator. The output waveform is now better than the previous one but not pure sinusoidal.
The redesigned setup is tested and the wave form is as shown in figure 2.19

![Wave form after redesigning](image)

Fig.2.19: Wave form after redesigning

### 2.6 CONCLUSIONS

1. A three phase 4.9kVA, 50Hz, 400V; SRA has been designed and fabricated.

2. In order to ensure the output waveform more sinusoidal the SRA has been redesigned by increasing the air gap by 1mm.

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**CHAPTER 3**

**ANALYSIS OF ALTERNATOR WITH RECTIFIER LOADS**

**3.1 INTRODUCTION**