ABSTRACT

Indian electrical industries supply industrial alternators for rectifier loads, arc furnace loads and thyristor load applications to various customers. These synchronous machines along with rectifier loads are also used in HVDC system and AC exciters. In such cases the harmonics will be injected in from the supply side of the alternator making the generator line current distorted to trapezoidal waveform. These harmonics increases the losses in stator conductors. Negative-sequence currents which are due to load imbalance, will also induce 100Hz components in the field and damper windings. The solid iron rotor in case of large synchronous machines will have induced currents due to harmonic and unbalanced loads which cause additional losses and consequently temperature rise. This thesis emphasizes about the design aspects, constructional features and experimentation on Solid Rotor Alternator (SRA) to study its behavior under harmonic loads and unbalanced loads.

The conventional laminated rotor is not adaptable for large rating synchronous generators as it suffers from the disadvantages which are due to mechanical stress, rigidity and critical speeds. In order to overcome these drawbacks a SRA is preferred in lieu of laminated one.

In addition to that, ease of manufacture, high torque per ampere at standstill, withstanding capability of high rotational
stresses and operating in unusual environment made SRA more suitable for high power ratings.

It is needless to say that the SRA is more adaptable for high power and high speed applications. The study of operational behavior becomes difficult for academia as all available alternators are invariably laminated rotors. Hence this constraint motivated to develop a prototype model indigenously.

A three phase 400V, 4-pole, 50Hz, 1500 rpm induction motor is considered, keeping its stator unaltered. Its squirrel cage rotor is replaced by solid rotor with DC field winding. The material used for rotor is chromium nickel steel. Core and shaft are forged together as one piece in the workshop which is exception in very large sizes. Two thirds of rotor is wound and the rest one third is left without slots to obtain sinusoidal field distribution. In case of turbo alternators Manganese bronze or steel wedge is driven into the mouth of each slot for the purpose of keeping the winding in place. Here, Hardened Glass Laminations (HGL) are used as wedge material.

The MG set is experimented by performing various tests on it.

i) Open Circuit Test (OCT) ii) Short Circuit Test (SCT)
iii) Direct load test iv) Heat run test
v) Balanced load test vi) Unbalanced load test
vii) 3-ph short circuit fault viii) L-L fault
OCT and SCT are performed to determine the Short Circuit Ratio. Direct load test is conducted to determine the efficiency of the machine. Heat run test to know the thermal capabilities of the machine. Unbalanced load test to determine negative sequence losses of the machine. 3-ph short circuit fault and line-to-line faults are created on no load and corresponding transient waveforms have been captured by transient recorder DL-750. An experiment is conducted on the MG Set to observe the input voltage and current of DC motor while SRA is fed with same amount of AC load and DC load. The difference in the two cases resulted into additional losses of SRA due to harmonics.

The method of harmonic compensation techniques of synchronous machine includes parks transformation, d-q-o mathematical model and equivalent circuit.

To overcome the disadvantages of passive filters, active power filters have been presented as the current harmonic compensator for reducing the Total Harmonic Distortion (THD) of the current and correcting the power factor of the input source.

A neuro controlled shunt active filter is designed to minimize harmonics using Artificial Neural Networks (ANN) toolbox of MATLAB/SIMULINK. An experiment is also carried out by connecting capacitors across the terminals of SRA.

By increasing the air gap length, the output waveform of three phase SRA is found improved. Efficiency of this developed small size
SRA is 85.66 %. Additional losses due to harmonics has been determined by performing relevant test as 2.36 W which is 0.42% of total losses. Machine constants like subtransient, transient and steady state reactance are obtained both from three phase symmetrical short circuit test and line to line short circuit test separately.

Commutation angle is of paramount importance in designing an alternator specifically for a rectifier load. The lesser the commutation angle, the higher operating power factor of system. Reduction in commutation angle is obtained by reducing \( L_d'' \), \( L_q'' \). The alternator used in this research work being cylindrical rotor without damper windings, the commutation angle is found initially by analytically and later by a computer program approach. It has been validated experimentally.

The percentage THD measured in the presence of a controlled shunt active power filter are within the IEEE harmonic standard IEC-519. The designed circuit compensates up to 27\(^{th}\) order harmonics. A hardware experiment is also conducted with capacitors and corresponding THD is recorded by power meter.

The analysis of SRA in this thesis is carried out based on equivalent circuit approach. The analysis can be taken based on electromagnetic field approach as further research. The prototype is developed without damper windings and with cylindrical rotor. Work can also be extended for a salient rotor with damper windings.