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17/ENG04/057
ELECTRICAL ELECTRONICS ENGINEERING

ELECTRICAL MACHINES (EEE326) ASSIGNMENT

Question 1: Discuss the effects of harmonics on synchronous machines (hint" identify the harmonics, state how they affect synchronous motors; state how they affect synchronous generators)

Solution:

IDENTIFYING THE HARMONICS

Harmonics are a distortion of the normal electrical current waveform, generally transmitted by non-linear loads. They are produced mainly due to the non-sinusoidal flux distribution, saturation, slotting effect due to the stator and rotor slots etc. in rotating machines.

HARMONICS FORMS:

The harmonics are grouped into positive (+), negative (-) and zero (0) sequence components.

- Positive sequence harmonics (harmonic numbers 1, 4, 7, 10, 13, etc.) produce magnetic fields and currents rotating in the same direction as the fundamental frequency harmonic.
- Negative sequence harmonics (harmonic numbers 2, 5, 8, 11, 14, etc.) develop magnetic fields and currents that rotate in a direction opposite to the positive frequency set.
- Zero sequence harmonics (harmonic numbers 3, 9, 15, 21, etc.) do not develop usable torque, but produce additional losses in the machine.

EFFECTS OF HARMONICS

Generators themselves can be affected by harmonic sources, in terms of efficiency losses, overheat, derating. One of the main reasons is the high impedance of generators, that will transfer easily current harmonic distortion into voltage harmonic distortion (i.e., affecting other loads supplied from that source). For the case of motors, we refer to them as loads of the electrical installation, more than voltage sources. But the direct effects of harmonics both for motors and generators are mainly the same. These effects include:

1) Vibration:

   The interaction between the positive and negative sequence magnetic fields and currents produces torsional oscillations of the motor shaft. These oscillations result in shaft vibrations. If the frequency of oscillations coincides with the natural mechanical frequency of the shaft, the vibrations are amplified and severe damage to the motor shaft may occur.

2) Torque rotation:
   The 5th Harmonic produces flux rotating in opposite direction to Main Flux in synchronous Motor. This flux produces Retarding Torque in Motor. Also, it will reduce the actual magnetic field and also bring distortion in main flux pattern.

3) Crawling in Motor:
   The 7th Harmonic creates dip in Torque Speed Curve of Motor at 1/7th the Synchronous Speed. This may result in motor running at 1/7th the Synchronous Speed. This is called Crawling.

4) Distortion:
   The 7th harmonic is in same phase of the fundamental and hence its magnetic field aids the main field. It brings that distortion and also there's chance of the material to get saturated.

5) Frequency (Skin Effect):
   Describes the magnetic property of confining alternating current towards the outer area of a conductor, the higher the frequency of that AC current. This "effective" reduced area (compared to real cross-sectional area of the conductor), will mean higher resistive losses directly proportional to frequency. So, for higher order harmonics, the Skin Effect can cause added losses or need for oversizing of conductors.

6) Conductor losses:
   Core losses (iron) increase with harmonics, caused by Eddy currents (loss increase with square of the frequency) and hysteresis, Also Copper losses, which are proportional both to ($Irms^2 \cdot R$)

7) Power Factor:
   Harmonics increase the Distortion Power (D), i.e., increase the Apparent Power (S) required by the system, while the "effective" real power at the fundamental frequency f1 (P1) does not benefit from that. This means higher current needs to be drawn from the PCC, so added wire section, and higher rating protection and distribution circuits yielding to derating.

Question 2: Justify technically why the stator windings of large generators are star connected

Solution

The stator winding of the large generators is generally connected in star because:

1. In a star connected stator, the voltage actually appearing across the coils of individual phases is reduced by a factor of 1.732. So, in case of a 33 KV alternator, the individual phase coils within the machine will be subjected to 33/1.732= 19 KV only. This means considerable saving in the cost of insulating material provided within the machine. Also, size of the alternator gets reduced due to lesser space required for accommodating insulating materials.

2. The stator winding of generators has a six-output terminal, in which three terminal short (make neutral point) and remaining three gives output which are possible only in star connection. So, we are connected in star
3. For star connected stator, the neutral is formed where one end of all the three winding is connected. The neutral point is connected to the neutral ground resistor. The earth fault can be detected if the current flows in the neutral. Under balanced load condition no current flows through the neutral.
4. Elimination of harmonics: Star connection facilitates a neutral connection which is instrumental in eliminating triple harmonics.
5. No circulating currents: In star connection we don't have circulating parasitic currents like in delta which lead to heating losses.
6. Since the induced emf in the phase winding of an generators is directly proportional to the number of turns, a star connected alternator will require lesser number of turns than a delta connected alternator for the same line voltage.

Question 3: Why is it that the armature for large machines is stationary?

1) The stationary armature coils can be insulated easily.
2) Higher peripheral speed can be achieved in the rotor.
3) As armature winding is stationary the natural cooling is more effective.
4) Only two slip rings are required to give DC supply to the field system.
5) More output is obtained as field winding is quite lighter than armature winding, output current can be easily supplied to the load circuit. Slip-rings and brushes are not necessary.
6) There are less chances of sparking in stationary arm. Winding comparatively to stationary rotor.
7) Commutation is a problem in rotatory armature.
8) As rotating winding is field winding which is comparatively light so chances of wear and tear is less.

Question 4: Why do brushless generators undergo less maintenance

The brushless generators have benefits of reduced regular maintenance due to elimination of brushes and reduced unscheduled maintenance due to redundancy. Also, brushless generators are better suited for less maintenance and constant usage because there are no dust collecting brushes to replace or fix, they have fewer internal parts that can be damaged, and the brushless generators does not have a contact zone, which considerably reduces wearing and maintenance.