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EEE326 ASSIGNMENT & SOLUTIONS

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

Harmonics: Harmonics by definition are a steady state distortion of the fundamental frequency (60 Hz). Harmonic distortion of current occurs when sinusoidal voltage is applied to a non-linear load (ex. electronic ballast, PLC, adjustable-speed drive, arc furnace, any ac/dc converter). The result is a distortion of the fundamental current waveform. This distortion occurs in integer multiples of the fundamental frequency (60 Hz). Hence, the 2nd Harmonic has a frequency = 2 x 60 = 120 Hz, the 3rd Harmonic = 180 Hz and so on. Voltage distortion, on the other hand, is generated indirectly as result of harmonic currents flowing through a distribution system

Effect of Harmonics

Since Harmonic Voltage means Voltage at higher Frequency, it has following effects

Skin Effect

In case of AC Current, Current flows in Periphery or Skin of Transmission Lines due to Self-Inductance in Conductors. At higher Frequency Skin Effect increases. Due to Skin Effect, Effective Resistance increases. This increases Loss and increase in Temperature.

Increase in Iron Loss in Transformers connected to Generator

Iron Loss consists of Hysteresis Loss and Eddy Current Loss. Hysteresis Loss $\propto f$ and Eddy Current Loss $\propto f^2$. Thus Iron Loss increases resulting in Higher Loss in Core of Transformer and Temperature is increased.

Retarding Torque in Induction Motor

5_{th} Harmonic produces flux rotating in opposite direction to Main Flux in Induction Motor. This Flux produces Retarding Torque in Induction Motor.

Crawling in Induction Motor

7_{th} Harmonic creates dip in Torque Speed Curve of Induction Motor at $1/7_{th}$ the Synchronous Speed. This may result in Induction Motor running at $1/7_{th}$ the Synchronous Speed. This is called Crawling.

Methods of reducing Harmonics in Synchronous Generator

There are various methods of reducing Harmonics but each method has got limitation as shown below.

Using Salient Pole Rotor

In Salient Pole Rotor, Flux produced is more Sinusoidal as compared to Cylindrical Rotor. However, in large Turbo Generator, outside Diameter of Rotor is large and it runs at 3000 RPM. Salient Poles are unable to withstand large Centrifugal Forces. Hence Cylindrical Rotor is used. It is a single Forging in which Slots are cut to accommodate Rotor Winding.

Large Air Gap between Stator and Rotor

Reluctance increases with large air gap. Ripple due to slot Harmonics decreases. But large air gap requires more MMF for maintaining Flux. Current in Rotor increases. This may lead to sparking between Brushes and Slip Rings. There will be higher temperature in Rotor.

Skewing in Slots of Stator Core by one Slot Pitch

Skewing means that at the other end of Stator Core, in place of Slot, Teeth will come and in place of Teeth, Slot will come. Slot Harmonics at both ends cancel each other. However manufacturing of Stamping used in Stator Core becomes very cumbersome.

Harmonic Filter

5_{th} and 7_{th} Harmonics have major contribution. 11_{th} and 13_{th} Harmonics may also come though there amplitude is less. At the Load end Harmonic Analyser are used to find out Harmonics and Harmonic Filters are installed to reduce these Harmonics.

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

Solution

Star type winding offers high voltage and low current and hence is most preferred because it is easier to transmit high voltages over the transmission lines than that of high current. This is mainly done to reduce the core or power loss (p = I2R). The more the current the higher the

losses. As a result, we opt for Star type windings than delta because delta windings tend to give out more current and less voltage and thus requires other equipment like step up transformers, relays to be added on extra thereby increasing the cost as well.

Majority of alternators that supply electricity to us, are big alternators working with higher voltages ranging from 11 KV to 33 KV. At such high voltages, star connected alternator becomes the obvious choice over delta connected one. The reason is explained below:

In a star connected alternator, 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.

The above advantages will not be available with delta connected alternators because in delta connection, phase voltage is equal to line voltage.

That is why large alternators are always star connected.

Alternators are connected primarily in star to achieve the following motives:

1. Lesser stress on insulation and Copper saving: Voltage per phase is less for a given line voltage which reduces insulation requirement and this also reduces the number of turns hence copper is also saved.
2. Easy protection: Neutral grounding is necessary to allow zero sequence currents to flow to the ground in case of a fault.
3. Elimination of harmonics: Star connection facilitates a neutral connection which is instrumental in eliminating triple harmonics.
4. No circulating currents

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

An alternator operates on the same fundamental principle of electromagnetic induction as a DC generator i.e., when the flux linking a conductor changes, an e.m.f. is induced in the conductor.

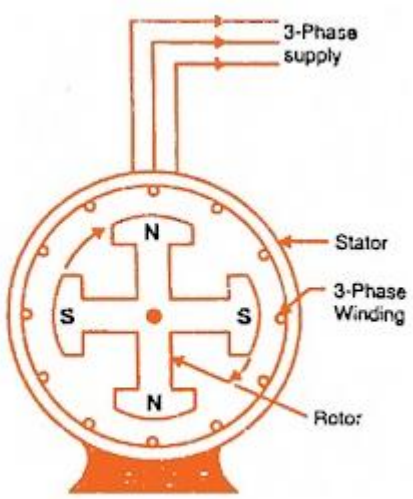
Like a DC generator, an alternator also has an armature winding and a field winding. But there is one important difference between the two.

In a DC generator, the armature winding is placed on the rotor in order to provide a way of converting alternating voltage generated in the winding to a direct voltage at the terminals through the use of a rotating commutator.

The field poles are placed on the stationary part of the machine. Since no commutator is required in an alternator, it is usually more convenient and advantageous to place the field winding on the rotating part (i.e., rotor) and armature winding on the stationary part (i.e., stator).

Reason for Stationary Armature

The field winding of an alternator is placed on the rotor and is connected to DC supply through two slip rings.



Armature of Alternator

The 3-phase armature winding is placed on the stator. This arrangement has the following advantages:

1. It is easier to insulate stationary winding for high voltages for which the alternators are usually designed. It is because they are not subjected to centrifugal forces and also extra space is available due to the stationary arrangement of the armature.
2. The stationary 3-phase armature can be directly connected to load without going through large, unreliable slip rings and brushes.
3. Only two slip rings are required for d.c. supply to the field winding on the rotor. Since the exciting current is small, the slip rings and brush gear required are of light construction.
4. Due to the simple and robust construction of the rotor, the higher speed of rotating DC field is possible. This increases the output obtainable from a machine of given dimensions.

Question 4: Why do brushless generators undergo less maintenance?

Brushless Alternators

Brushless alternators are better suited for more long-term, constant usage because there are no brushes to replace or fix, and have fewer internal parts that can be damaged. A brushless alternator has two sets of rotors that spin together to generate and transfer the electrical current. A brushless alternator has a second, smaller generator on the end of the equipment instead of brushes, which it uses to transfer any electrical current. This is an immediate advantage over a brushed alternator because there are no brushes to replace or repair, saving you long term money and time. A disadvantage of a brushless alternator, however, is the much higher initial cost, as opposed to a brushed alternator. This is mostly because of the higher amount of materials used in a brushless alternator. Brushless alternators, however, are also more suited to be your primary alternator/generator and are more capable of long-term use. In the long run, you will save money by buying a brushless alternator, but keep in mind that it's an investment because of the higher cost when compared to a brushed alternator.

Whether you're looking for a quick and cheap short-term brushed alternator, or a more advanced and expensive long-term solution brushless alternator, always keep in mind how much power you need to generate as well as your budget. You shouldn't feel pressured into spending more money just for a long-term alternator, but the worst-case scenario is underestimating just how much power your job requires. Use our power calculator to determine your power needs, or contact a trained Absolute Generators specialist to determine if a brushed or a brushless generator is right for your operation.