IWATT ENOBONG UDO

18/ENG04/080

ELECTRICAL/ELECTRONICS ENGINEERING

EEE 326: ELECTRICAL MACHINES II

ASSIGNMENT

1.) Discuss the effects of harmonics on synchronous machines.

Answer:

In synchronous machines, voltages and currents are induced, which are in sinusoidal waveforms.But in practice, these sinusoidal waveforms will deviate to form non-sinusoidal waveforms. These non-sinusoidal waveforms are expressed in terms of Fourier transforms which are the sum of series of sinusoidal waveforms.

These harmonic components can be represented as follows.

Fundamental: $e1 = Em1 \sin (t \pm \theta 1)$

2nd Hermonic $e2 = Em2 \sin (2 t \pm \theta 2)$

3rd Harmonic $e3 = Em3 \sin (3 t \pm \theta 3)$

5th Harmonic $e5 = Em5 \sin (5 t \pm \theta 5)$ etc.

In case of alternators as the field system and the stator coils are symmetrical the induced emf will also be symmetrical and hence the generated emf in an alternator will not contain any even harmonics.

-Slot Harmonics: As the armature or stator of an alternator is slotted, some harmonics are induced into the emf which is called slot harmonics. The presence of slot in the stator makes the air gap reluctance at the surface of the stator non uniform. Since in case of alternators the poles are moving or there is a relative motion between the stator and rotor, the slots and the teeth alternately occupy any point in the air gap. Due to this the reluctance or the air gap will be continuously varying. Due to this variation of reluctance ripples will be formed in the air gap between the rotor and stator slots and teeth. This ripple formed in the air gap will induce ripple emf called slot harmonics.

Effect of Harmonics on induced emf:

The harmonics will affect both pitch factor and distribution factor and hence the induced emf. In a well designed alternator the air gap flux density distribution will be symmetrical

and hence can be represented in Fourier series as follows.

The RMS value of the resultant voltage induced can be given as

Eph2 = [(E1)2+ ....+ …… (En)2]

**(A)2 Means A Square

Effect of Harmonics of pitch and distribution Factor:

The pitch factor is given by Kp = cos /2, where is the chording angle.
For any harmonic say nth harmonic the pitch factor is given by Kpn = cos n α/2
The distribution factor is given by Kd = (sin mβ /2) / (m sin β/2)

For any harmonic say nth harmonic the distribution factor is given by
Kdn = (sin mn β/2)/(m sin nβ/2)

This is the detailed info about Harmonics In Synchronous Machines,Minimization Methods of Harmonics.Effect of Harmonics on induced emf.

- Increased Heating

General

Iron losses such as eddy current and hysteresis losses, are produced in the core of motors and generators due to the alternating magnetic field. The amount of eddy current loss varies as the square of the frequency, while hysteresis loss is directly proportional to frequency. Thus, higher frequency voltage components (i.e. harmonic voltages) generate additional losses, which result to higher operating temperature of the core and the surrounding windings. Nevertheless, winding losses are of more concern than iron losses. Basically, I^2R losses in the machine windings vary as the square of the RMS current. Therefore, an increase in the RMS current due to harmonics should be minimized since it will lead to higher winding losses. Moreover, actual losses would be slightly higher than calculated values because of skin effect. Furthermore, stray losses - winding eddy current losses, high frequency rotor and stator surface losses, and tooth pulsation losses will increase due to harmonic voltages and currents.

Motors

Core and stray losses may become significant for an induction motor with skewed rotors. Single-phase motors are the most affected.

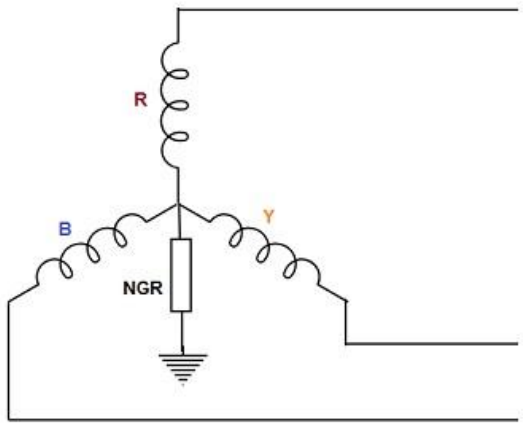
Generators

The heating effect of nonlinear loads on generators is greater compared to transformers. This is because a generator has higher reactance and impedance, that when paired with high frequency flux changes could cause stator heating. Also, high frequency currents will induce currents in the pole faces and hunting winding and hence cause rotor heating. Subsequently, generators supplying nonlinear loads should be derated based on the generator reactance.

2.) Justify technically why the stator windings of large generators are star connected.

Answer:

1) STAR connection provides a neutral point. This neutral point is very important from the stability point of view of generator. Generally, the neutral point is grounded through NGR (Neutral Grounding Resistor). Neutral grounding provides a path for the flow of circulating current during the unbalanced loading condition of generator. In addition to this, it also provides a path for the flow of zero sequence current during the single line to ground fault / double line to ground fault. Furthermore, grounding of neutral point maintains the voltage of healthy phase to the normal phase voltage.



If there were no neutral, the voltage of the healthy phases would have been increased during the ground fault, which may eventually lead to insulation failure of the healthy

phases. Thus a single line to ground fault may result in three phase fault due to insulation failure.

Also, the grounding of neutral through NGR limits the value of fault current and hence damage to the stator armature winding.

2) The insulation requirement in STAR connection is less. Since phase voltage is $1/\sqrt{3}$ times i.e. 57.7% ($100 / \sqrt{3} = 57.7\%$) of the line voltage, therefore the insulation requirement of phase winding reduces. This is a great advantage from economic point of view.

Since the generated emf in phase winding,

$Ef = \sqrt{2}\pi fN\text{Ø}$

where N = Number of turns

3) In STAR connection Phase voltage = Line Voltage / $\sqrt{3}$, whereas phase voltage = line voltage in DELTA connection. Therefore for generating the same line voltage, the requirement of number of turns in STAR connection of armature winding will be less as compared to DELTA connection.

4) STAR connection eliminates the triplen harmonics in the generated terminal voltage of generator armature winding. Read “How Harmonics Eliminated from Alternator Generated Voltage?” to know the reason.

3.) Why is it that the armature for large machines is stationary?

Answer:

1. It is easier to collect current through brushes from stationary armature in case of generators.
2. When armature winding is stationary and field winding rotates we get more output as field winding is quite lighter than armature winding.
3. There is less chances of sparking in stationary arm. Winding comparatively to stationary rotor.
4. Commutation is a problem in rotatory armature.
5. As armature winding is stationary the natural cooling is more effective.
6. As rotating winding is field winding which is comparatively light so chances of wear and tear is less.

4.) Why do brushless generators undergo less maintenance?

Answer:

Brushless generators 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.

Less brushes, abrasion of brushless generator is mainly on bearings, from the view of a mechanical point, brushless generator is almost a maintenance-free motor, when necessary, just need to do some dust removal maintenance. Brush generator has excellent low-speed torque performance and high torque characteristics, which are irreplaceable.