

I'm not a robot





























power is inversely proportional to XS. This is the power which keeps alternators in synchronism during parallel operation and maintains the stability. Any disturbances from equilibrium conditions are compensated by synchronizing power. For low value of SCR, XS is very large and synchronizing power is very low. As synchronizing power decreases, tendency of alternators to remain in synchronism decreases. This decreases the stability. Thus low SCR puts the stability limit. Key Point : Lower the value of SCR, low is the stability limit. 4. The SCR can be increased by increasing the air gap but this needs more to obtain same e.m.f. Hence the pole size increases which increases the overall size and cost of the machine. 5. Practically the SCR value is selected between 0.5 to 1.2. Example 2.13.1. Show that the short circuit ratio of an alternator is the reciprocal of the per unit value of the synchronous reactance at rated voltage. Solution : The Short Circuit Ratio (SCR) is defined as the ratio of the field current required to produce rated voltage on open circuit to the field current required to produce rated armature current with the armature terminals shorted while the machine is mechanically rim at NS. Consider O.C.C and S.C.C. shown in the Fig. 2.13.2. Thus short circuit ratio is reciprocal of XS adjusted to saturation at rated voltage. Example for Practice Example 2.13.2 A 2200 V, 50 Hz, 3-phase, star connected alternator has an effective resistance of 0.5 per phase. A field current of 30 A produced the full load current of 200 A on short circuit and a line to line e.m.f. of 1100 V on open circuit determine, 1) The power angle of the alternator when it delivers full-load at 0.8 p.f. (lagging). If the SCR of the alternator: [Ans.: S = 14.35, SCR = 0.3189] Review Question 1. Explain the significance of short circuit ratio. Share copy and redistribute the material in any medium or format for any purpose, even commercially. Adapt remix, transform, and build upon the material for any purpose, even commercially. The licensor cannot revoke these freedoms as long as you follow the license terms. Attribution You must give appropriate credit, provide a link to the license, and indicate if changes were made. You may do so in any reasonable manner, but not in a way that suggests the licensor endorses you or your use. ShareAlike If you remix, transform, or build upon the material, you must distribute your contributions under the same license as the original. No additional restrictions You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits. You do not have to comply with the license for elements of the material in the public domain or where your use is permitted by an applicable exception or limitation. No warranties are given. The license may not give you all of the permissions necessary for your intended use. For example, other rights such as publicity, privacy, or moral rights may limit how you use the material. Short Circuit Ratio, or SCR, is the ratio of field current required to generate rated voltage under open circuit condition, to the field current required to circulate the rated armature current under three phase short circuit condition. It is an important quantity of synchronous machine which helps in estimation of operating characteristics. It is also useful for obtaining the size of machine for a given rating and type. The value of Short Circuit Ratio varies from 0.5 to 0.8 for Turbo Generator, 1 to 1.4 for Hydro generator and 0.4 to 0.5 for synchronous condenser. Calculation Short Circuit Ratio can easily be obtained from the Open Circuit (OCC) and Short Circuit Characteristics (SCC) of Synchronous machine. Figure below shows the OCC and SCC. From the above figure and definition, SCR = If for rated OC voltage / If for rated SC current = (oa / od) (1) But triangle oab and ode are similar triangles, therefore oa/od = ab/de From (1), SCR = (ab/de) (2) Direct axis reactance Xd of synchronous machine is defined as the ratio of open circuit voltage for a given field current, to the armature short circuit current for the same field current. Therefore, direct axis reactance Xd for field current oa is given as Xd = (ac/ab) The per unit (p.u) value of direct axis reactance Xd is obtained by dividing it by base impedance p.u value of Xd = (ac/ab) / Base Impedance But, Base Impedance = ac Volt / rated = de Amp. Therefore, base impedance = (ac/de) p.u value of Xd = (ac/ab)/(de/ac) = (de/ab) From (2), Xd in p.u = 1/SCR SCR = 1 / Xd in per unit Thus, short circuit ratio is equal to the reciprocal of the per unit value of direct axis synchronous reactance. The more the value of Xd, the lesser will be the short circuit ratio. Significance of Short Circuit Ratio Value of short circuit ratio, or SCR, affects both the size and operating characteristics of synchronous machine. Significance of SCR can be better understood by considering the following cases: Low SCR: Low value of SCR simply means greater value of Xd. The voltage regulation is greatly affected by direct axis reactance. More the value of Xd, the poor will be the voltage regulation. This means that, the terminal voltage will widely vary with variation in load. In order to maintain constant terminal voltage, the field current needs to be varied widely and therefore the load on the excitation system will increase. Greater value of direct axis reactance Xd also affects the stability of synchronous machine. The synchronizing power of synchronous machine is defined as the degree by which the machine has a tendency to get synchronized with the infinite Grid just after experiencing disturbance. Low value of synchronizing power means, the machine will have fewer tendencies to get synchronized again after recovering from disturbance. Synchronizing Power is inversely proportional to reactance Xd, lower value of short circuit ratio results in lower stability limit. The only advantage of lower SCR is the lower value of armature current during three phase short circuit. High SCR: High value of short circuit ratio gives improved voltage regulation. Thus the terminal voltage is practically constant during the load variation. It also results in better stability limit due to increased value of synchronizing power. But the disadvantage of high value of SCR is increased armature current during three phase short circuit and increased machine size. Size and Cost of Machine: SCR greatly affects the size and hence the cost of machine. To better understand the effect of Short Circuit Ratio on the size of machine, let us assume that the air gap length is doubled. The mutual inductance Md, in terms of direct axis (d-axis) synchronous reactance Xd can be written as, Md 1/d-axis reactance Doubling the air gap length doubles the reluctance. Therefore, the magnetic flux linkage becomes half. Thus the mutual inductance reduces to half of its original value. To maintain same open circuit terminal voltage, field current must be doubled. The short circuit current Isc is given as Isc = Ef/Xd = Md If / 3Ld where Ld is direct axis inductance. When air gap length is doubled, mutual inductance Md and self inductance Ld are equally affected. Therefore, the field current required to circulate the rated armature current remains same. It is thus observed that when air gap length is doubled, field current is doubled for maintain same open circuit voltage. Field currentAs per the definition of SCR, doubling the air gap length doubles the short circuit ratio. With double the air gap, the field current required to generate the same open circuit terminal voltage is doubled. This requires greater cross-section of field winding and hence greater field copper. This increased amount of copper field winding can only be wound if the field pole size is increased. Subsequently, the machine diameter increases and hence overall size, weight and cost of machine increases. In a synchronous machine, the short-circuit ratio (SCR) is an important factor. The SCR affects the physical size, operating characteristics and cost of the synchronous machine. Low Value of SCR With a low value of SCR, the synchronous machine is very sensitive to the load variations, i.e., the alternator has a large variation in terminal voltage with a change in load. In order to keep the terminal voltage constant, the field current of the machine is to be varied over a wide range. Also, for a small value of SCR, the synchronising power of the machine is small. The synchronising power keeps the machine in synchronism, thus, the synchronous machine with a low stability limit. Therefore, an alternator with a low SCR is less stable when operating in parallel with other alternators. The armature current of the synchronous machine under short-circuit conditions is small for a low value of SCR. With a high value of SCR, a synchronous machine has a better voltage regulation and improved steady-state stability limit, but the armature current under short-circuit conditions is high. Effect of SCR on the Size, Weight, and Cost of Machine The physical size and cost of the synchronous machine are affected by the short-circuit ratio. The excitation voltage for a synchronous machine is given by, E = Ef + Ia Xs Where, Ef = Excitation voltage, Ia = Armature current, Xs = synchronous reactance. Therefore, E = Ef + Ia Xs. Hence, for a given terminal voltage, the field current required to circulate the rated armature current at the short circuit, an indication of the quantity of copper and iron in the electrical and magnetic parts. Machines with high short-circuit ratios will contain more materials. The standard figure quoted for a turbo-alternator is between 0.8 and 1.0. The effect of a high short-circuit ratio gives an improved generator stability at times of load changes. List of alternator losses: Friction Windage 2R losses in the stator and field windings Hysteresis and eddy current losses in the iron of the stator and rotor field circuits Click on the arrows to learn more about hydrogen windage loss. Reasons Why Generators Fail Foreign Object Damage Problem: Can come from external sources or failure of internal components, they pick up energy from the spinning rotor and do extensive damage. Prevention: Inspect on a regular basis all internal parts that are prone to failure or can be dislodged. Inspection tests can be a combination of visual inspection along with ultrasonic or magnetic particle tests on rotating components. Stator Winding Vibration Problem: Primarily a design-related problem. Affects large (>300Mw) generators that have insufficient end winding bracing to limit the movement of end turns. Prevention: Proper bracing of the end winding is required to limit motion caused by electromagnetic forces. Rotor Winding Distortion Problem: Caused by poor end turn blocking support design or by foreshortening of the rotor coils. Foreshortening is caused by thermal forces that compress rotor coils. Prevention: Proper design of rotor coils and bracing to support the coils under axial load is essential. Rotors should be tested for turn-to-turn shorts at operating speed. Overheating Stator Or Rotor Problem: This can lead to insulation failure, shorting of turns, and ground faults. Overheating can result from blocked ventilation passages caused by shifting insulation components or slot wedges. Prevention: Inspect on a regular basis to ensure all rotor wedges are locked in place preventing migration and thus blocking cooling passages. Rotor Vibration Problem: Many causes: turn-to-turn shorts, rotor coil foreshortening, electrical grounds, mechanical imbalances, overheating, etc. Prevention: Comprehensive vibration measuring is effectively when combined with a regular maintenance program. Contamination Problem: Air-cooled machines, dirt, and dust cause tracking which can lead to electrical ground faults. Prevention: Inspect air filters on a regular basis, the filters must be checked and cleaned regularly. Polarization index (PI) tests give a good indication of the overall cleanliness of the rotor winding. Stator Core Damage Problem: Stator core looseness can occur over time as pre-tensioned bolts relax. A loose core results in insulation wear to coils and laminations resulting in hot spots and core-to-coil failures. Prevention: Inspect bolt tightness on a regular basis. The Short Circuit Ratio (SCR) of a synchronous machine is defined as the ratio of the field current required to generate rated voltage on an open circuit to the field current required to circulate rated armature current on a short circuit. The short circuit ratio can be calculated from the open-circuit characteristic (O.C.C) at rated speed and the short circuit characteristic (S.C.C) of a three-phase synchronous machine as shown in the figure below. From the above figure, the short circuit ratio is given by the equation shown below. Since the triangles Oab and Ode are similar. Therefore, the direct axis synchronous reactance Xd is defined as the ratio of open-circuit voltage for a given field current to the armature short circuit current for the same field current. For the field current equal to Oa, the direct axis synchronous reactance in ohms is given by the equation shown below: The per-unit value of Xd is given as: But, the base impedance is: Therefore, from equation (1) and equation (6), we get From equation (7) it is clear that the short circuit ratio is equal to the reciprocal of the per-unit value of the direct axis synchronous reactance. In a saturated magnetic circuit, the value of Xd depends upon the degree of saturation. Significance of Short Circuit Ratio (SCR) Short Circuit Ratio is an important factor of the synchronous machine. It affects the operating characteristics, physical size, and cost of the machine. The large variation in the terminal voltage with a change in load takes place for the lower value of the short circuit ratio of a synchronous generator. To keep the terminal voltage constant, the field current (If) has to be varied over a wide range. For the small value of the short circuit ratio (SCR), the synchronizing power is small. As the synchronizing power keeps the machine in synchronism, a lower value of the SCR has a low stability limit. In other words, a machine with a low SCR is less stable when operating in parallel with the other generators. A synchronous machine with a high value of SCR had a better voltage regulation and improved steady-state stability limit, but the short circuit fault current in the armature is high. It also affects the size and cost of the machine. The excitation voltage of the synchronous machine is given by the equation: For the same value of Tph Excitation voltage is directly proportional to the field flux per pole. The synchronous inductance is given as: Therefore, Hence, the short circuit ratio is directly proportional to the air gap reluctance or air gap length. If the length of the air gap is increased, the SCR can be increased. With the increase in the air gap length, the field MMF is to be increased for the same value of excitation voltage (Ef). Hence, to increase the value of field MMF either field current or the number of field turns has to be increased. All this requires a greater height of field poles and, as a result, the overall diameter of the machine increases. Thus, a conclusion is that the large value of SCR will increase the size, weight, and cost of the machine. The typical values of the SCR for different types of machines are as follows: For cylindrical rotor machines, the value of SCR lies between 0.5 to 0.9. In the case of the Salient-pole machine, it lies between 1.0 to 1.5. And for synchronous compensators, it is 0.4. This is all about Short Circuit Ratio of a Synchronous Machine. Short circuit ratio (SCR) is defined as the ratio of field current required to produce rated voltage on open circuit to the field current reqd. to circulate rated current on short circuit. Explanation The Fig shows open circuit and short circuit characteristics of an alternator. According to definition, Effect of SCR on Machine performance 1. Voltage regulation 2. Stability 3. Parallel operation 4. Short circuit Current 5. Cost and size of the machine 1. Voltage Regulation 3. Parallel operation 4. Short circuit Current 5. Cost and size of the machine 1. Voltage Regulation 3. Parallel operation 3. Parallel operation: SCR = 1/Xs, as SCR is Xs/V. Psyclnd, Short circuit current 5. Cost and size of the machine as SCR is Xs/Zs Isc and hence cost of control equipment reduces. For salient pole machines SCR value varies from 0.9 to 1.3. For turbo alternators SCR value varies from 0.7 to 1.1. Page 2 Length of the air gap: Length of the air gap is a very important parameter as it greatly affects the performance of the machine. Air gap in synchronous machine affects the value of SCR and hence it influences many other parameters. Hence, choice of air gap length is very critical in case of synchronous machines. Following are the advantages and disadvantages of larger air gap. Advantages: (i) Stability: Higher value of stability limit (ii) Regulation: Smaller value of inherent regulation (iii) Synchronizing power: Higher value of synchronizing power (iv) Cooling: Better cooling (v) Noise: Reduction in noise (vi) Magnetic pull: Smaller value of unbalanced magnetic pull Disadvantages: (i) Field mmf: Larger value of field mmf is required (ii) Size: Larger diameter and hence larger size (iii) Magnetic leakage: Increased magnetic leakage (iv) Weight of copper: Higher weight of copper in the field winding (v) Cost: Increase over all cost. Hence length of the air gap must be selected considering the above factors. Calculation of Length of Air Gap: Length of the air gap is usually estimated based on the ampere turns required for the air gap. Armature ampere turns per pole required ATa = 1.35 Tphkw/p Where Tph = Turns per phase, lph = Phase current, kw = winding factor, p = pairs of poles No load field ampere turns per pole ATNo = SCR x Armature ampere turns per pole ATa = SCR x ATa Suitable value of SCR must be assumed. Ampere turns required for the air gap will be approximately equal to 0.7 to 75% of the no load field ampere turns per pole. ATg = (0.7 to 0.75) ATa Air gap ampere turns ATg = 796000 Bgkg/Air gap coefficient or air gap contraction factor may be assumed varying from 1.12 to 1.18. As a guide line, the approximate value of air gap length can be expressed in terms of pole pitch For salient pole alternators: lgr = (0.012 to 0.016) x pole pitch For turbo alternators: lgr = (0.02 to 0.026) x pole pitch Synchronous machines are generally designed with larger air gap length compared to that of induction motors. Page 3 Design of stator winding: Stator winding is made up of former wound coils of high conductivity copper of diamond shape. These windings must be properly insulated so that the induced emf in all the phases of the coils must have the same magnitude and frequency. These emfs must have same wave shape and be displaced by 120° to each other. Single or double layer windings may be used depending on the requirement. The three phase windings of the synchronous machines are always connected in star with neutral earthed. Star connection of windings eliminates the 3rd harmonics from the line emf. Double layer winding: Stator windings of alternators are generally double layer lap windings either integral slot or fractional slot windings. Full pitched or short chording windings may be employed. Following are the advantages and disadvantages of double layer windings. Advantages: (i) Better waveform: by using short pitched coil (ii) Saving in copper: Length of the overhang is reduced by using short pitched coil (iii) Lower cost of coils: saving in copper leads to reduction in cost (iv) Fractional slot windings: Only in double layer winding, leads to improvement in waveform Disadvantages: (i) Difficulty in repair: difficult to repair lower layer coils (ii) Difficulty in inserting the last coil: Difficulty in inserting the last coil of the windings (iii) Higher Insulation: More insulation is required for double layer winding (iv) Wider slot opening: increased air gap reluctance and noise Number of Slots: The number of slots are to be properly selected because the number of slots affect the cost and performance of the machine. There are no rules for selecting the number of slots. But looking into the advantages and disadvantages of higher number of slots, suitable number of slots per pole per phase is selected. 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