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Analysis and Simulation of Inter-Turn Fault Of Synchronous Generator Using MATLAB

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Abstract: The paper represents a comprehensive analysis of the inter-turn faults of a synchronous generator. In today's power system, we have used three phase synchronous generator to generate electric power, thus we all always try to reduce the loss in order to improve the efficiency of the alternator. We basically focus more on the stator winding faults. Stator winding has unbalanced loading, field failure and stator winding fault (including line to ground fault, line to line fault and double line to ground fault, three phase fault and inter turn fault) Alternator stator inter turn faults are considered to be rare and therefore they are not taken into that serious consideration while designing the protection system for the alternator. But we knew that there could be an inter-turn short circuit fault in the stator winding of the alternator. Early detection of inter turn faults will eliminate damage to the stator core and adjacent coils, reducing repair costs and generator outage times. Since inter turn fault causes imbalance in phase voltage, this concept is discussed in this paperfor inter turn fault detection. The negative sequence voltage of the generator is used as a fault indicator for inter turn fault detection. This new approach is done using MATLAB software. Also, this method works for external as well as internal fault and helps in keeping the generator winding healthy.
Keywords: Inter Turn fault, internal and external faults, Internal Negative, Sequence Generator Voltage.

I. INTRODUCTION

Synchronous generator is an important core component of power system and synchronous generator is an important electrotechnical energy converter. Once damaged, the network cannot continue to function properly. The synchronous generator itself will have a variety of faults. But we mainly focused on the stator inter-turn winding fault. It is essential to locate and protect the alternator from those faults to limit potential damage. The fault in generator mainly occurs due to insulation breakdown of stator winding coil.

There are different types of stator winding faults:
1) Phase to phase fault (Open circuit fault)
2) Phase to earth fault (Ground fault)
3) Inter turn fault (Isolated turn fault)

A. *Phase to Phase Faults*

Phase-to-phase faults occur very rarely, they canoccur on the end of the stator coil or in slots if the windings include two coil sides in the same slot. In the latter case, the fault would involve the Earth in a very short time. The phase fault current is not limited by the method of earthing the neutral point.

B. *Phase to Earth Faults*

The most likely mode of insulation failure is phase to earth fault. The use of earthing impedance limits the earth fault current and hence stator damage. An earth fault involving the stator core results in the iron burning at the point of the fault and joining the pieces together. Replacement of faulty conductors may not be a very serious matter (dependent on set rating/voltage/construction) but damage to core cannot be ignored, as welding of laminations may result in local overheating. The damaged area can sometimes be repaired, but if severe damage has occurred, partial core reconstruction will be necessary. A flashover is more likely to occur in the end-winding region, where the electrical stress ishighest. The resulting forces on the conductors would be very largeand could result in extensive damage, requiring partial or total rewinding of the generator.

C. *Inter-turn Fault*

Inter turn fault of synchronous generator occurs when the loss of dielectric strength of the insulating winding of the machine. Thermal stress is probably the most recognized cause of winding insulation failure, the electric sparks that generate electricity in the air bubbles in the winding insulation, such it happens.

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An inter turnfault involves too few turns of the winding in the field distribution over time which may occur in single phase or may be an inter turn fault between phases. Inter-turn faults are more likely to occur within the stator slot than the end winding. For simplicity, an inter-turn fault is modeled in one step. However, there is sufficient data to indicate that an inter turn fault may exist in the stator winding ofa synchronous generator. An alternator is exposed to a variety of operating conditions that result in varying thermal, mechanical and electrical stresses. These stresses weaken the insulation between the windings and in this process cause an inter turn fault in the winding. The new technique used in this paper for detection of faults is superior to existing protections in the aspect of sensitivity and protection range.

The symmetrical component technique is being preferred for fault diagnosis of an alternator. Each power system can be represented by three decoupled sequence networks namely, positive, negative and zero sequence respectively. Under balanced condition an alternator voltage has only positive sequence EMF, there is no negative sequence and zero sequence EMF induced init.

The stator winding inter turn fault produces the unbalance in the generator phase voltages.

II. SUBSYSYTEM OF SYNCHRONOUS GENERATOR

The state space model of alternator is described in this section that will be used for estimation of negative sequence reactance for inter turn fault analysis. his example shows how to model a faulted PMSM using Simscape Electrical. Normallywhen modeling a SM, you can represent each winding as a single entity with associated inductance, induced back EMF, and mutual inductive coupling to adjacent windings. However, when a winding fault occurs, the single entity assumption breaks down.fig.1.

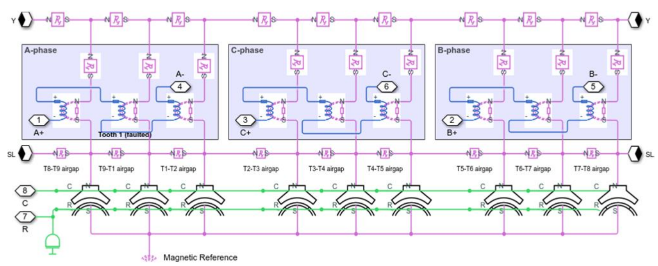

Fig1.Model architecture of Synchronous generator

The equation for flux linkages of the stator and rotor windings can be expressed as,

$$\varphi_S = L_{SS} I_S + L_{Sr} I_r$$

$$\varphi_r = L_{Sr} I_S + L_{rr} I_r$$

Where L_{SS}, L_{Sr} and L_{rr} refers to stator-stator, stator-rotor, and rotor-rotor inductances respectively.

To analyse the protection sensitivity, typical alternator ratings are taken for example in this paper, for which the major data is listed in Table 1.

Table 1. Generator ratings and parameters

Rated Power	1100MVA
Rated Voltage	18KV
Rated Frequency	50Hz
Stator Resistance	0.0025pu
Stator Leakage Reactance	0.14pu
D-Axis Reactance	0.92pu
Q-Axis Reactance	0.71pu
D-Axis Transient Reactance	0.30pu
Q-Axis Transient Reactance	0.228pu
D-Axis Sub-Transient Reactance	0.22pu
Q-Axis Sub-Transient Reactance	0.29pu
Field Resistance	0.0043pu
Field Leakage Reactance	0.2pu

III. INTERNAL NEGATIVE SEQUENCE VOLTAGE

To extract negative sequence voltage and current D-Q transformation is used considering that the reference frame is rotating in clockwise direction. For the positive sequence phase quantities, the transformed D&Q axis quantities will be second order quantities. For negative sequence phase quantities, the transformed D&Q axis voltages and currents will be dc quantities.

Negative sequence voltage, $V_2 = V_q + jV_d$
Negative sequence current, $I_2 = I_q + jI_d$
Negative sequence impedance, $Z_2 = jX_2$
Internal Negative sequence voltage, $E_2 = V_2 + I_2 Z_2$

A. Simulation Model

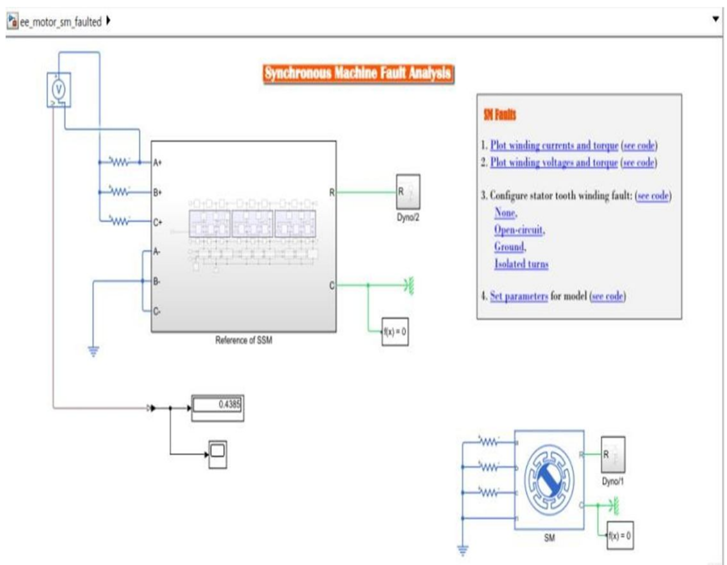

Fig.2 Simscape model of synchronous generator withInter-turn fault condition

B. Simulation Waveforms

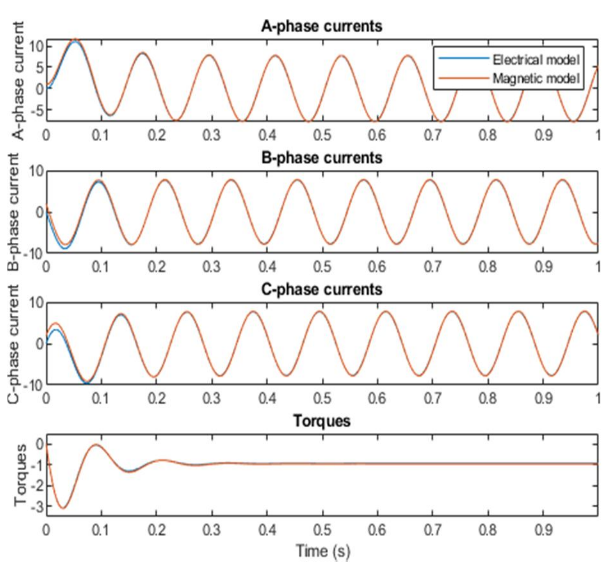

Fig.3 Phase current and torque waveform forNormal condition

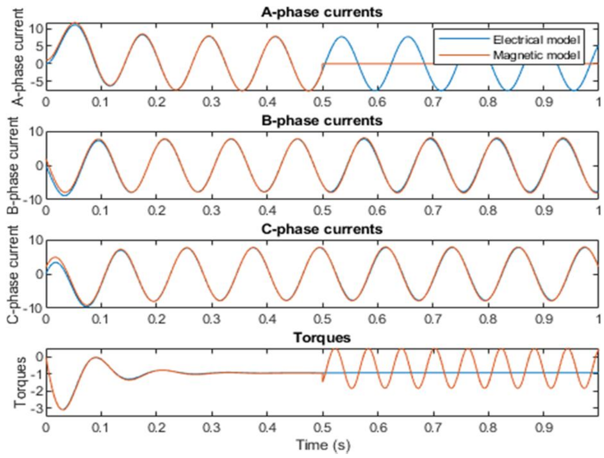

Fig 4 Phase current and torque waveform for OpenCircuit Fault condition

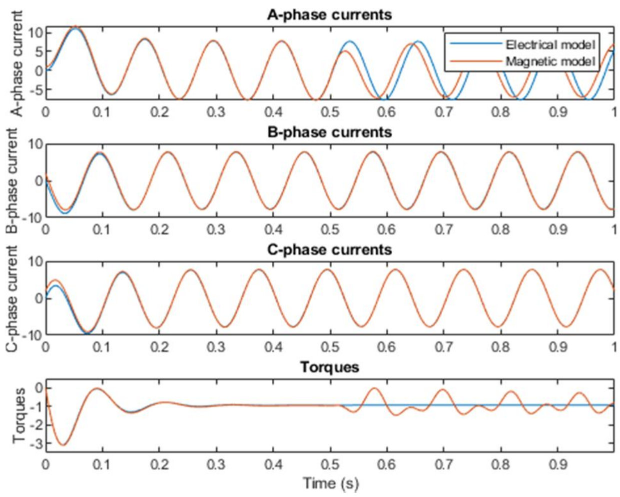

Fig.5 Phase current and torque waveform for short Circuit Fault condition

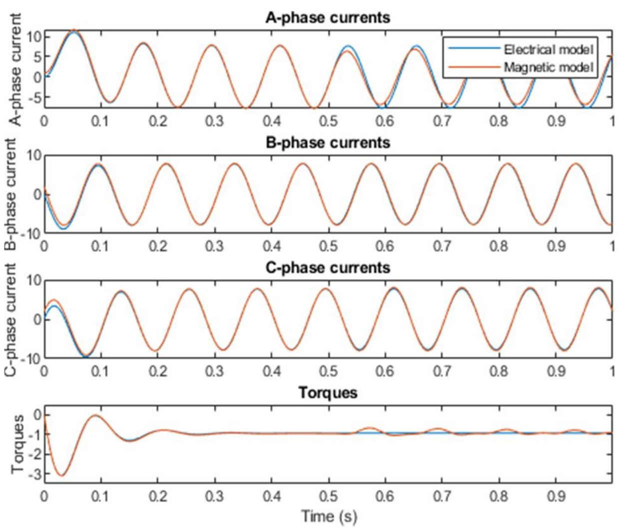

Fig.6 Phase current and torque waveform for Interturn Fault condition

IV. RESULTS

Fig: 3 shown output waveform of voltage, current and torque of an synchronous generator and stator healthy or normal operating condition in which all three-phase winding are in with each other. The simulation output waveform of synchronous generator under various phase current and torque waveform for normal operating condition. Fig: 4 to fig:6 in which the fault occurrence in system is shown during the simulation time t=0.3 to t=0.5 sec. due to the fault in system there is a fluctuation in different voltage and current parameter. of synchronous generator is clearly visible through the simulation output waveform result.

V. CONCLUSION

The mew modification of these paper for the stator inter turn fault protection of large capacity of synchronous generator ispresented. the overall performance of thise method evaluate for both external and internal faults. This method can be used the synchronous generator negative sequence voltage ofthe synchronous generator.

And can detect the minor stator turn to turn faults for very efficiently. Also the internal and external faults differentiated. There are no additional sensor are required to implement scheme. Since it only need the current and terminal voltage data of synchronous generator. This schemecan be very easily implemented at a cheaper cost.

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