Stator winding fault detection of an Alternator using MATLAB

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***Abstract*— The paper represents the comprehensive analysis of stator winding faults of an alternator. An alternator is main component of power system which plays a big role in whole system for security and stability. The conventional system only detect symmetrical and unsymmetrical faults, they will not detect inter turn fault. The fault detection of stator winding is an effective and important measure to ensure the safe operation of generator. Early detection of stator winding fault would eliminate damage to stator core & adjacent coils, also reduce repairing cost and outage time of generator. As stator winding fault causes unbalance in phase voltage, this concept is discussed in this paper for the detection of stator winding fault. The negative sequence voltage of generator is used as fault indicator for fault detection. This new method is done using MATLAB software. Also, this method operate for external as well as internal fault and helps the generator winding keep healthy.**

***Keywords*— stator winding fault, internal negative sequence voltage, internal and external faults.**

I. INTRODUCTION

Synchronous generator is the core component of electrical power system, once it get defected the network cannot continue working properly. There are many types of faults will be occurring in the power system or alternator itself. So, there is necessity to detect and protect the alternator from those faults to limit the possible damage. Majorly faults occur in an alternator is due to insulation breakdown of stator coils. Different types of stator winding faults are

a) Phase to ground fault
b) Phase to phase fault
c) Inter turn fault

The stator inter turn faults in an alternator are taken to be rare and so that it cannot be taken into serious consideration while designing the protection system. However, there is sufficient data to indicate that the inter turn fault can exist in stator winding of an alternator. An alternator exposed to variety of operating conditions resulting in varying thermal, mechanical and electrical stresses. These stresses lead to weakening of insulation between the windings and this process led to inter turn fault in winding. Recent methods to protect an alternator have been proposed in[2]. In order to detect and protect the machine against various faults for turbo generator using negative sequence impedance directional protection is explained in[3]. A fuzzy neural network based inter turn fault detection scheme for an alternator using the negative sequence component of voltage and current is proposed in[4]. A correlation technique to identify different types of faults occurred in an alternator are explained in[5]. The performance analysis of all above methods using negative sequence quantities shows poor sensitivity to detect stator winding faults[1]. 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 in it.
The stator winding fault produces the unbalance in the generator phase voltages.

II. MODELLING 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 stator winding fault analysis. The mathematical modelling is necessary to study synchronous generator under various conditions. A synchronous generator consists of four basic windings namely three identical and symmetrical and two damper windings as shown in fig.1.

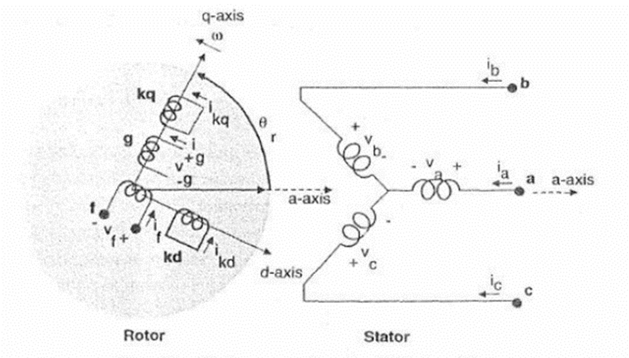

Fig.1. circuit representation of an alternator

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.

For given test system of synchronous generator connected to a 3 phase RL load,

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, $E_2 = V_2 + I_2 Z_2$

IV. SIMULATION MODEL

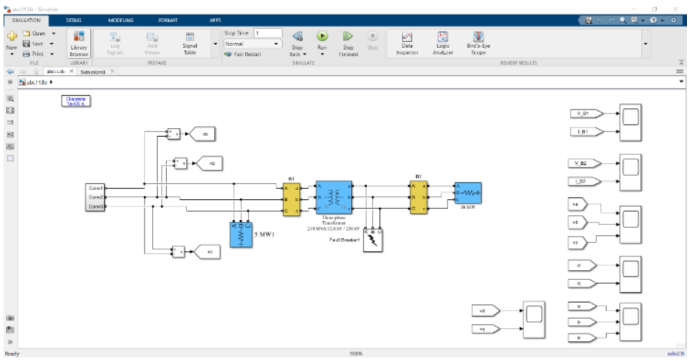

Fig.2 Simulation model under healthy / normal operation

The simulation model consists of synchronous generator connected with hydraulic turbine and excitation system as per the parameters referred from table 1. The 3-phase fault block is used to create a fault in the model. The simulation is done for the alternator connected with 50MW resistive load.

The stator winding fault is more dangerous and are likely to cause a damage to the expensive machinery therefore, early detection is absolutely necessary to clear such faults in the quick possible time to minimize the extent of damage of alternator.

For creating fault in simulation model, 3 phase fault block is used from Simulink library. Fault resistance 0.5ohm, switching time between 0.3 to 0.5 sec., and snubber resistance, snubber capacitance inf. is selected. When fault is created using this block, the alternator detects and shows the output waveform variation during switching time period in the result of simulation.

V. RESULTS

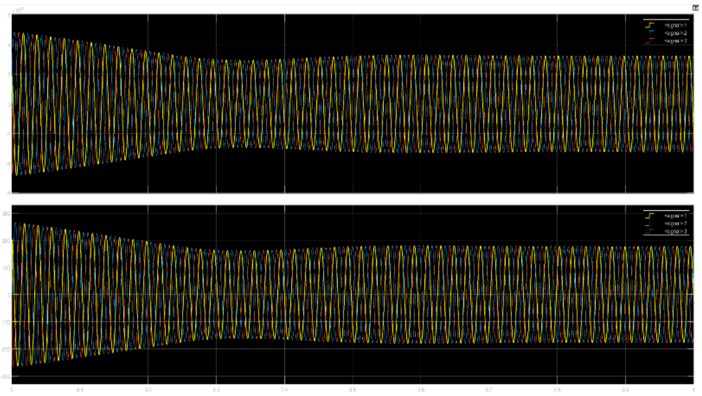

Fig 3. Voltage and current output waveform of alternator under healthy condition

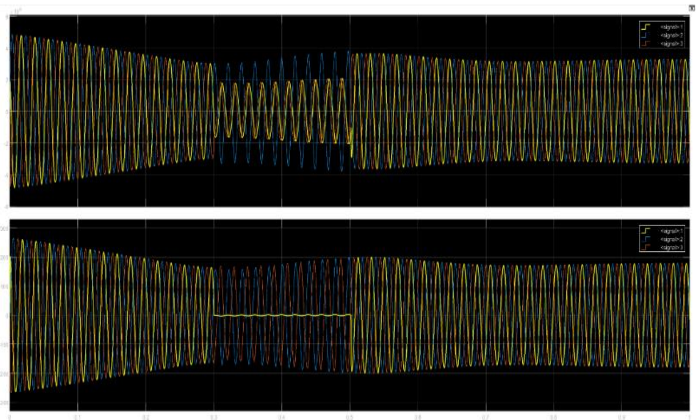

Fig 4. Voltage and current waveform for L-G fault without inter turn fault

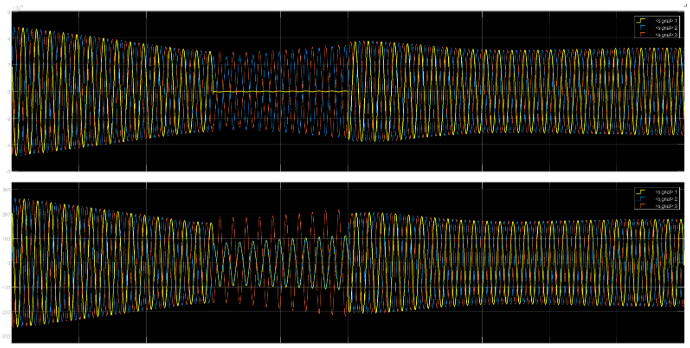

Fig 5. Voltage and current waveform for L-L fault without inter turn fault

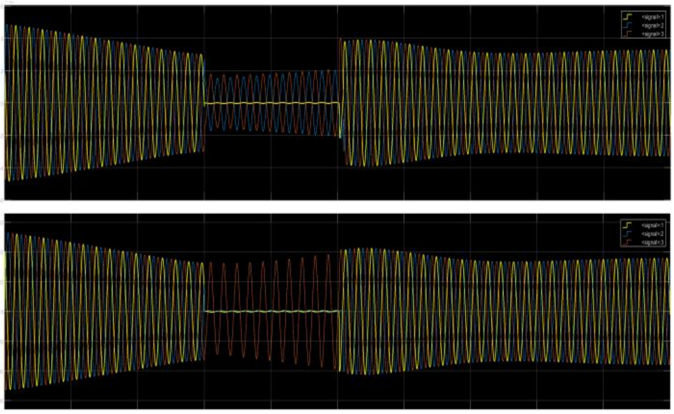

Fig 6. Voltage and current waveform for L-L-G fault without inter turn fault

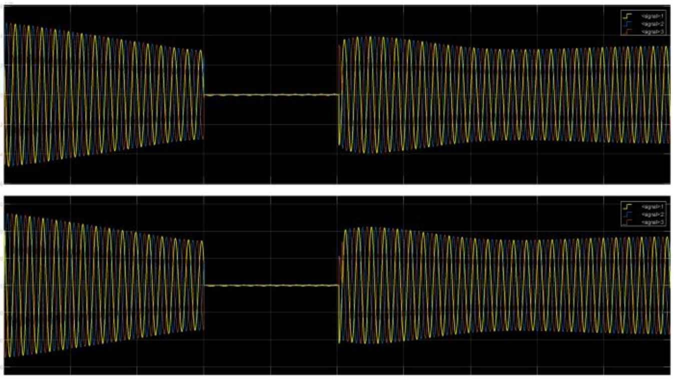

Fig 7. Voltage and current waveform for L-L-L fault without inter turn fault

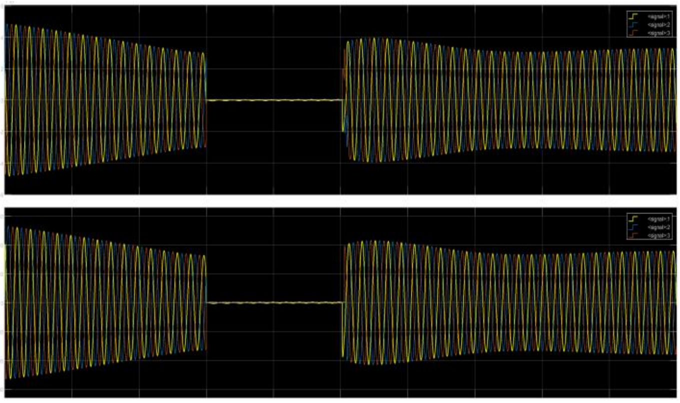

Fig 8. Voltage and current waveform for L-L-L-G fault without inter turn fault

Fig. 3 shows the output waveform of voltage and current of an alternator under healthy or normal operating condition in which all three phases are in phase with each other. The simulation output waveform of an alternator under various symmetrical and unsymmetrical fault conditions are shown from figure 4 to figure 8. In which the fault occurrence in a system is shown during the simulation time t= 0.3sec to t= 0.5sec. Due to the fault in a system, there is a fluctuation in the different parameter (voltage and current) of an alternator is clearly visible through this simulation output waveform results.

VI. CONCLUSION

In this paper a new concept is used for the detection of various faults in a large alternator is presented. The performance of this method was evaluated for both internal and external faults. This method uses internal negative sequence voltage of an alternator to detect minor to minor faults. No additional sensors are required to implement this method since it only needs the terminal voltage and current data of an alternator. this method is reliable and efficient for the detection of faults, also maintain the stability.

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