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EXPERIMENT IN PROTECTING THE EXCITATION CIRCUIT OF A TURBOGENERATOR FROM DOUBLE GROUNDS

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[Figures are appended.]

In one of the hydroelectric stations of Mosenergo, a unique system of protecting the excitation circuit from double grounds was devised and installed for a 50,000-kw generator (manufactured by Siemens - Schuckert, with a split stator, 1,500 rpm) having a fixed ground in the rotor winding at one point (38% from the plus ring).

The protection was carried out by standard methods without compensation for the alternating current. The actuating mechanism consisted of a maximum current relay of the ET 71/0.25 (KnETZ) type and a potentiometer with a resistance of 110 ohms (nominal exciter voltage of the generator was 220 V).

The actuating current for the maximum current relay was set originally at 0.12 amps. After connecting the protector in the excitation circuit of the generator, it was established by tests that, in a balanced bridge arrangement, an AC current of 100 - 130 ma flows in the relay winding causing the contacts of the relay to vibrate. The setting of the relay had to be increased temporarily to 0.3 amps, but despite this the relay went into operation during nonsymmetrical short circuits in the external network.

The flow of alternating current in the relay winding, as tests showed, is caused by the presence of an induced emf in the rotor shaft of the generator which is produced by the unsymmetrical magnetic flux in the stator and pulsations in the rotor current. Since the generator bearing on the exciter side is insulated from the casing, then the only closed circuit possible for the emf induced on the generator shaft is the one which includes the following: generator shaft, the point of contact of the excitation winding on the rotor iron, excitation winding, protective circuit, relay winding, and the grounding system of the station.

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The grounding of the rotor shaft of the generator on the exciter side cannot be carried out due to the appearance of bearing currents. The induced emf on the exciter side of the rotor shaft has a value of about 4 - 4.5 volts.

By excluding the grounding system of the station from the protective circuit, and by connecting the current relay directly to the rotor shaft of the generator (specially installed brushes and cables), the alternating current flowing through the relay was reduced from 130 to 80 ma and stray currents from the grounding system were eliminated from the relay winding.

To reduce the alternating current passing through the relay to permissible values, a locking choke coil was inserted in series with the relay. With a balanced bridge arrangement the alternating current flowing through the relay was reduced from 130 to 19 ma, which permitted an increase in the protective sensitivity by setting the relay actuating current to 120 ma.

The scheme of protection against grounds at two points (Figure 1), as proposed by the author, is undoubtedly more reliable than the standard type recommended in "Guiding Instructions on Relay Protection," and is easier to put into practice than the protective circuit with AC compensation, since the latter requires a special current transformer and a special relay with two windings.

The choke coil can be prepared on the spot (it is possible to use, as a choke coil, the secondary winding of a current transformer, class D or 0.5 with a transformer ratio of 2000/5, 2500/5 or 3000/5, if a reserve transformer is available). It is necessary that the choke coil operate with low induction on the iron (in the region of increasing magnetic permeability) and high reactance of the choke coil with low effective resistance. With the fulfillment of these conditions the choke coil reactance will increase as the voltage across its terminals increases (Figure 2).

A satisfactory coil may be constructed using the following data: number of turns, 400; cross-sectional area of core, 32 sq cm; and effective resistance, 0.43 ohms.

A PbD wire with a diameter of 2.65 mm was used for the winding.

Figure 3 shows how the alternating current flowing through the winding of the protective maximum current relay, in a balanced bridge arrangement, varies as the alternating emf increases. As can be seen from the graph, the setting on the relay has a considerable factor of safety.

[Figures follow.]

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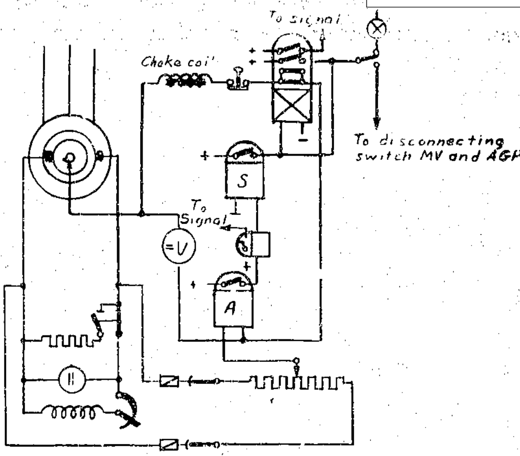


Figure 1. Schematic Diagram for Protecting the Excitation Circuit of a generator From a Double Ground, With a Locking Choke Coil

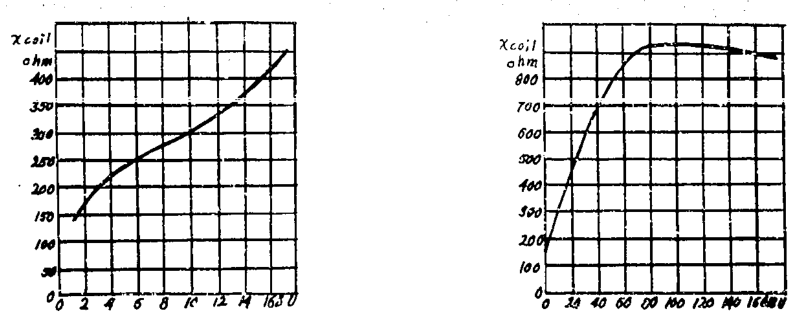
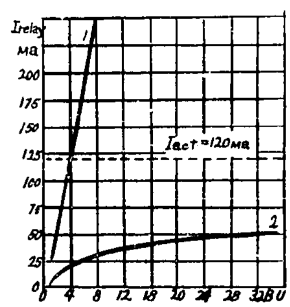


Figure 2. The Curve $x=f(U)$ of the Locking Coil (Taken at the Commercial Frequency)



1. Without choke coil

2. With choke coil

Figure 3. Relationship Between the Change in the Unbalanced Alternating Current Flowing Through the Protective Relay and the Induced Voltage on the Rotor Shaft of the Generator

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