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THE PROCESSES USED IN PROTECTION OF SYNCHRONOUS GENERATORS IN NAVAL ELECTRICAL NETWORKS

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Abstract: *The paper presents the possibilities of synchronous generators protection from electro-energetic naval system. These four processes are analyzed: differential-longitudinal protection; protection against rotor short circuits; maximal protection with current cutting; protection through reactance coils. Specific conditions are analyzed on board a ship, any defects that occur to a synchronous generator and ways to reduce their effects.*

Keywords: *synchronous generator, short circuit, protection, reactance coils, relay, transformer*

1. INTRODUCTION

Essential feature of electric plants on ships is complexity. Each ship should have its own source of electricity. On the ship there are an electric distribution network, power consumers of the most diverse types, lighting installations, electric heaters, radio-communication equipment, signaling and automation, various mechanisms and devices and other electrical installations with special designation (degaussing plant, cathodic protection installation, installation of radioactive detection, rolling stabilizing plant, and so on) [1,2,3].

Electrical installations of ships must have a big robustness and a greater running safety conditions in operation due to the climatic and technical conditions on-board and the fact that during the voyage the ship becomes an isolated system.[4,5]

Effect of listing and oscillations upon the ship is the appearance of strong supplementary shear forces as a result of the strong gyroscopic and components of the gravitational force. To minimize this effect, all

the electric motors with horizontal shaft mount so that the shaft is parallel to the ship, because in contrast the tilting in the longitudinal plane is less than that in the transverse plane.

2. WAYS OF PROTECTION OF MARINE GENERATORS

Normal operation of a synchronous generator can be perturbed by inner defects or abnormal external network. Internal defects in particular are due to short circuits in the stator or rotor windings (des-excitation). Quick elimination of these defects is necessary in order to avoid destroying the generator by thermal effects of electro-dynamic currents short circuit [6,7,8,9,10,11,12].

Quick disconnection of the generator is carried out: by main switch; by reducing the induced electro-motor voltage in the stator; by reducing or interrupting excitation current; by rapid des-excitation switch in rotor circuit.

Longitudinal differential protection of a synchronous generator is based on comparing the meanings and values of the entry and exit currents of each phase of the generator.

Principle mono-line diagram of such protections is presented in Figure 1. In order to achieve that scheme synchronous generator grounding must be accessible, and the two current transformers TC_1 and TC_2 of each phase must have equal transforming reports and identical characteristics.

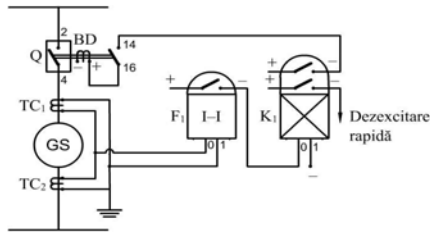


Fig. 1 Longitudinal differential protection and command of a synchronous generator
 GS –synchronous generator; Q –switch; BD – release coil; K_1 –intermediate relay; TC_1 , TC_2 –current transformers; F_1 –current differential relay.

In the event of a short circuit inside the generator secondary coil's currents of the two current transformers sums through maximum relay F_1 , it acts and excite the intermediate relay K_1 those trigger main switch Q and des-excitation quick automat (A.D.R.). Diagram ensures a snapshot switch in case of a short circuit in the synchronous generator's stator windings.

The diagram for the protection against rotor short circuits of synchronous generators, Figure 2, includes a maximum current relay F_1 , an intermediate relay K_1 , a transformer T having one of secondary winding terminals connected to the ground and a capacitor C in order to separate the rotor DC circuit of an AC circuit bounded to the ground.

In case rotor winding grounding of synchronous generator GS, it closes the AC circuit consisting of the secondary side of the transformer T, maximal relay F_1 , condenser C and Earth, which determine the switching of relay F_1 . Through normally open contact of the relay F_1 is that excites the intermediary relay K_1 through its contacts command triggering generator and rapid des-excitation of excitation coil.

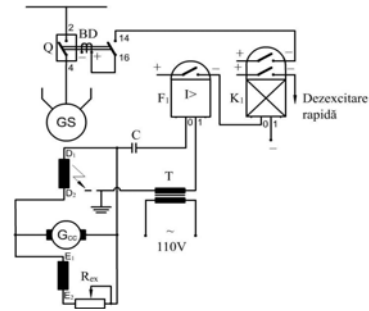


Fig. 2 Protection and command against rotor short circuits electric diagram
 GS –synchronous generator; Q –switch; BD – release coil; G_{cc} –excitatrice; R_{ex} – rheostat to adjust excitation; F_1 –maximum current relay; K_1 – intermediate relay; T – transformer; C – condenser.

Maximal protection with current cutting of a synchronous generator is used against multi-phased short circuits and external of generator overload. In Figure 3, is shown wiring diagram of a maximum protection with current cutting. Maximum current relays $F_1 \dots F_4$ acts on the external short circuits and excite the time relay K_1T , which for reasons of protection selectivity has the largest timing from the system. Time relay K_1T excite intermediate relay K_2 only if previous protection (of networks and transformers) does not act, causing to trigger generator with adjusted timing.

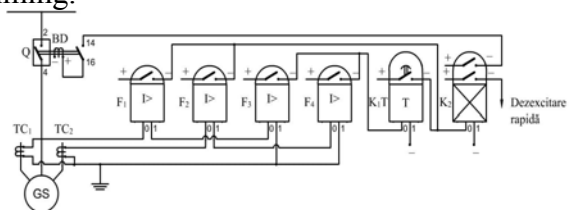


Fig. 3 The maximal protection and command wiring diagram with the current cutting of a synchronous generator
 GS –synchronous generator; TC_1 , TC_2 –current transformers; Q –switch; BD –release coil; $F_1 \dots F_4$ –maximum current relays; K_1T – timing relay; K_2 –intermediate relay.

Violent short circuits are signaled by the maximum current relays F_1 and F_2 (set to a start value greater than of the maximum current relay F_3 , F_4) causing instantaneous switching of K_2 relay which command



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generator triggering from network and its rapid des-excitation. These relays provide so-called cutting intense short-circuit currents.

Protection of synchronous generators can be achieved through reactance coils. Reactance coils are appliances which serve to limit the short circuit currents in the electrical circuit of high power and to maintain voltage at the bars, in an emergency, to an acceptable level, which ensures the operation without interruption of unaffected consumers. Limiting value of short circuit currents is by installing the reactance coils at the collectors bars of power plants and also at the lines that goes from these bars, (placed as in Figure 4), which performed the suitable operation conditions for the most sensitive items of equipment in case of those breakdowns: cables (in terms of thermal stability), switches (in terms of power breaking), allowing the choice of equipment for lower values of short circuit current.

Reactance coil is a coil without iron core (in order to have a constant inductivity) under 35 kV voltages is accomplished in the air. Hardening windings against electro-dynamic forces can be done by partial coverage of it in concrete or epoxy resins.

For voltages exceeding 35 kV, reactance coils of exterior type, cooling medium is mineral oil contained inside a tank in which lies and a screen.

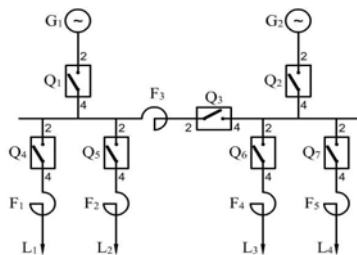


Fig. 4 Connection in the network of the reactance coils wiring diagram
F₁ ...F₅—reactance coils; Q₁ ...Q₇— switches;
G₁, G₂—synchronous generators.

Main parameter of reactance coil is bobbin reactance (X_r) whose main effect is the voltage drop on the coil. Percentage reactance (reported) $X_r * [\%]$ is an indicator of the current limitation possibilities and is usually (6-8)% for outgoing cables and (8-12)% for reactance coils designated for collectors bars.

To highlight the effect of reactance coil in protected circuit Figure 5, it was presented the voltage drop in a wire, at the nominal and in the short-circuit regimes. Note that the size of the voltage drop on the reactance coil in short-circuit regime, ensure the U_{rem} voltage with the value nearest with nominal and short-circuit current is limited.

Reactance coils, in air constructive model are without iron core and embedded in concrete. For embedding the current ways, made of aluminum or copper, 6-10 columns of concrete are used. Between the turns of the coil is let empty for cooling air access. Concrete coil is treated in order to not worsen the dielectric stiffness of coated insulation, after drying being covered by a non-hygroscopic varnish. The coils of the 3 phase can be installed both vertically and horizontally.

Disadvantages of reactance coils, usually recessed in the concrete are: complicated processing and drying technology as well as gross weight and dimensions.

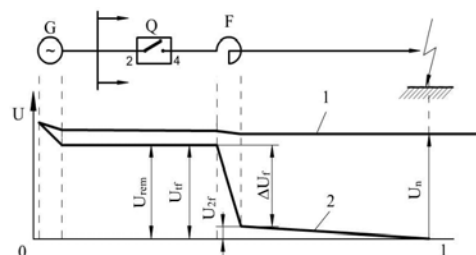


Fig. 5 The role of reactance coil in short circuit protection

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At the reactance coils mounted in oil tank, measures must be taken to limit the magnetic flux through the tank walls to avoid as a result both the oil and the tank to be overheated. Because of this, inside the tank it is mounted a ring made of copper or aluminum, fixed on the walls of the tank.

Compensation is even better with the electric lower resistance of the screen

Conditions imposed by normative rules to reactance coils are: overvoltage must not produce grounding or breakdowns in coils; thermal and electrodynamic stability –to be high; voltage drops in normal running mode must not exceed (1–3)% of nominal voltage; loss of power at the coil to be between (0,2 – 0,5)% of the power passing through the coil.

3. CONCLUSIONS

The vast majority of defects are damaging of the insulation which leads to the appearance of short-circuits.

Short-circuit current of a large value impose to electrical equipment and consumers important thermal and electrodynamic effects and at the same time leads to an increase of tension drops on all impedances passed, causing a general voltage drop in the network.

Electrical protection equipment is designed to limit the effects of emergency (damaged) running mode to protect consumers, electrical equipment and electric generators. Protection devices must sense the appearance of an abnormal regime and to isolate the damaged area by means of commutation. In order to be effective protection must be fast, sensitive, selective and more reliable in operation.

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