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MODERN METHODS USED IN PROTECTION OF ELECTRICAL NETWORKS ON MERCHANT SHIPS

Drd. Ing. M.Sc. RADU Serghei[1]
Prof. Univ. Dr. Ing. Capt. SAMOILESCU Gheorghe[2]
[1]Marine Ch. Eng. / Electric Ch. Eng. - Barklaw Constanta (N.C.M.)
[2]“Mircea cel Batran” Naval Academy – Constanta

Abstract: *Essential feature of electrical installations on ships is complexity. Today, a ship no matter how small it is inconceivable without an electrical installation. Each ship has to carry with it its own power source. On the ship there is a power distribution network, power consumers of various types, lighting, heating, household facilities, signal installations and automation of various mechanisms and devices, radio/satellite communications installations and other special-purpose electrical equipments (demagnetization installation, installation of cathodic protection, installation of signalling radioactivity, anti-rolling stabilizers plant, etc.).[11].*

This complexity of electrical installations on ships required for their construction and operation of a large number of specialists. In shipyards and in research and design institutes is possible specialization by type of equipment. On board ship, where there is few staff, officer must know all electromechanical problems proper functioning of the electrical system on board.[2].

Electrical equipment protections are designed to limit the effects of failure/emergency mode, to protect the electrical equipment and electrical generators and consumers. Protective devices must notify the occurrence of abnormal mode of operation and to isolate the damage sequence by switching devices. To be effective protection must to be sensitive, rapid, selective and more reliable.[1].

1. Introduction

The protection circuit design has to keep in mind that failure/emergency mode can damage not only supervised equipment but also the electrical installation as a whole. Often the damage caused by interruption of electricity supply to consumers is much higher than the cost of equipment damaged by abnormal operating regime.

A common defect in electrical installations, and which consisted of damage to insulation is the grounding. In a network with isolated neutral, grounding one phase is not in itself a defect, the non-leading to important disruption of operation. Grounding current may lead to unbalanced load of generators; load being of capacitive type can cause rise of voltage, which in certain conditions become dangerous. Also, a current flow through the ground can cause disturbances in power lines near the defects, especially in the telecommunications, by inducing tension that can reach dangerous levels. Like short-circuit, earth fault arc can be net or by arc. Arch can jump to other phases thus transforming the grounding into the short-circuit.[6].

Different is the intermittent arc, which consists of repeated extinction and reigniting of the grounding arc, extinction occurring in the moments of current passing through zero value and re-ignition in the moments when the alternative voltage reaches sufficient value for re-priming in still ionized medium. Arc flash can produce over-voltages that are about $3U_{pfase}$. Moreover, even if a net grounding, a network with isolated neutral, damaged phase gain ground potential, and voltage in respect to the ground of non-damaged phases increase 3 times, becoming equal to the voltage between them and the damage phase. Network surges when there a grounding, may cause a second earth fault on another phase, defect known as double-grounding, which is equivalent to a two-phase short circuit through resistance (resistance path through the earth).

Another category of defects that arise in electrical installations, other than those mentioned above, which were all based on damage of insulation is the interruptions of conductors (not only breaks the conductors themselves, but also a burning fuse on a stage, open a single phase separator e.t.c.). Such defects, however, is rare and most often is accompanied by a short circuit or grounding. First, the reasons that cause these types of defects are due exceeded those materials resistance to mechanical, thermal and, especially, electrical stress. Second, defects reason can be due to decrease below normal of material strength, either due to wear and aging (especially for electrical insulation), or to the action of external factors (chemicals, moisture, dirt, e.t.c.). [5].

Finally, it cited as causes of defects rather frequent, operating personnel mistakes as: the wrong connections, the introduction of foreign bodies in plants, insufficiently prepared manoeuvres, which can lead to large increases in installations overload. Percentage distribution of different types of defects is the following: single-phase short circuit, 65%; two-phase short circuit with grounding and the double grounding, 20%; two-phase short circuit without grounding, 10%; three-phase short circuits, 5%. In energetic systems, outside actual failures may occur deviations from normal operation, which also produce disruption and damage. They consist, in essence, in deviations of the operating parameters (voltage, current, frequency) from their nominal values. Abnormal regime most common operation is the overload. It consists in an increase in current over nominal values and may be caused by unexpected load increase, or decrease, for various reasons of the generating sources power. Overload is an unacceptable mode of continuous operation, primarily because generate overload (especially thermal) of plants, secondly, pass through systems of currents that exceed the nominal values produce pronounced decreases in voltage, which results in absorbing by consumers of currents even greater (to maintain constant power), thus causing a decrease in the voltage.[6], [11].

Another abnormal regime is the appearance of oscillation between generating units when they operate with different frequencies, the oscillation can also lead to total disruption.

2. Synchronous generators protection

Normal operation of a synchronous generator can be disrupted by internal defects or abnormal regimes outside network. Internal defects are mainly due to short circuits in stator windings or rotor (des-excitation). Rapid elimination of these defects is necessary to avoid destruction by thermal effects or electro-dynamic short circuit currents of generator.[3], [4].

Quick disconnection of generator from the grid is maid by main switch **Q** by reducing induced electric voltage in the stator and by reducing or stopping the excitation current through the switch of quick des-excitation (**ADR**) in the rotor circuit.

Longitudinal differential protection principle of a synchronous generator is based on the comparison of meanings and values of the input and output currents of each phase of the generator. Principle single line scheme, of this protection is shown in the figure below. To achieve this scheme, synchronous generator neutral should be accessible, and the two current transformers on each phase $\mathbf{TC_1}$ and $\mathbf{TC_2}$ should have equal processing reports and features identical.

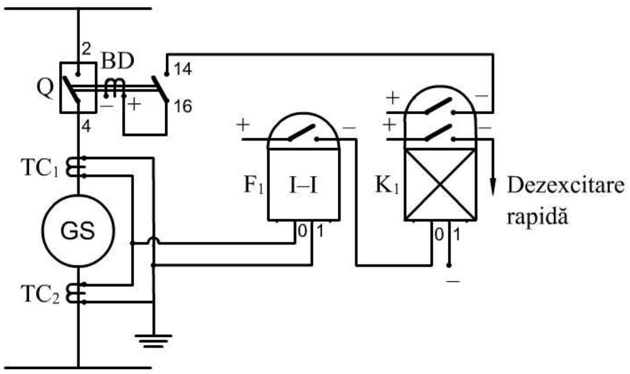

Fig.1 Single-line electric scheme of a synchronous generator longitudinal differential protection and control. GS- synchronous generator, Q-switch, BD- shutter coil, TC_1, TC_2- current transformers, F_1- current differential relay, K_1- intermediate relay.

If a short circuit inside the generator, currents in the secondaries of the two current transformers are added together through the maximum relay $\mathbf{F_1}$, it works and excite intermediate relay $\mathbf{K_1}$ which trigger the master switch **Q** and the des-excitation fast automated-switch (**ADR**). The scheme ensures instantaneous tripping of the synchronous generator winding at short circuits.[5].

Protection scheme against synchronous generators rotor short circuits comprises a maximum current relay $\mathbf{F_1}$, an intermediate relay $\mathbf{K_1}$, a **T** transformer with secondary winding having one terminal grounded and a capacitor **C** to separate the rotor c.c. current circuit of earthed a.c. circuit.

In a grounding of synchronous generator rotor winding **GS**, it close a.c. circuit consisting of transformer secondary coil **T**, $\mathbf{F_1}$**-** maximum relay, the capacitor **C** and ground, which cause $\mathbf{F_1}$ relay drive. Through the normally open contact of $\mathbf{F_1}$ relay, excited $\mathbf{K_1}$ intermediate relay which by its contacts command generator switch out and rapid onset of excitation winding.

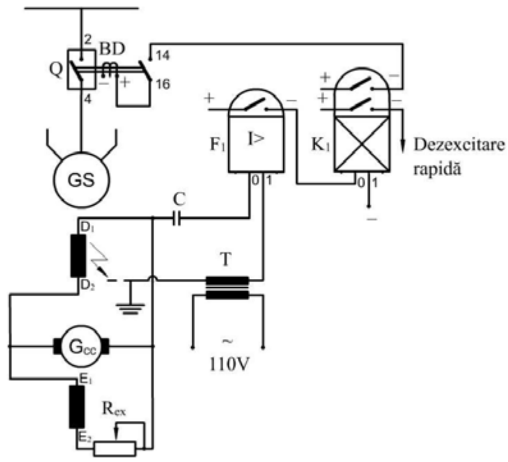

Fig.2 Single-line electric scheme of protection against short circuits and rotor control. GS-synchronous generator, the main switch Q, BD- shutter coil; Gcc-excitatrice, Rex-excitation rheostat adjustment, the maximum current relay F_1, K_1 intermediate relay, T-transformer, C-condenser.

Synchronous generator maximum protection with current cutting is used against multi-phase short circuits and generator external overloads. The figure below illustrates the maximum protection single-line scheme with current cut. Maximum current relays $\mathbf{F_1}$ **...** $\mathbf{F_4}$ acts at the occurrence of external short circuits and excite $\mathbf{K_1T}$ time relay, which for reasons of selectivity has the highest protection from system timer. $\mathbf{K_1T}$ timer relay excite $\mathbf{K_2}$ intermediate relay only if previous protections (the networks and transformers) does not work, causing the onset generator with adjusted timing.

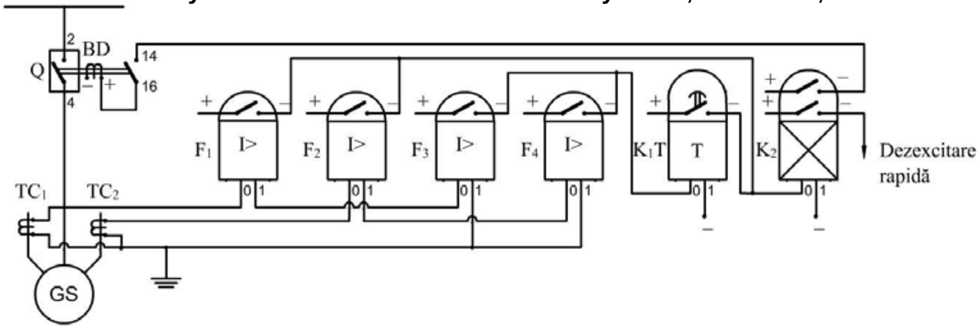

Fig.19 Synchronous generator protection and control performed with maximal power cut single line electrical diagram. GS-synchronous generator, TC_1, TC_2-current transformers, Q -main switch, BD-coil shutter, F_1 ... F_4-maximum current relay, K_1T-timing relay, K_2-intermediate relay.

Violent short circuits are notified by the maximum current relays $\mathbf{F_1}$ and $\mathbf{F_2}$ (adjusted to a starting value greater than the maximum current relays $\mathbf{F_3}$, $\mathbf{F_4}$) causing instantaneous relay $\mathbf{K_2}$ closing which command triggering generator from the network and its rapid des-excitation. These relays provide so-called current cutting for intense short-circuit currents.

3. Conclusions

One of the main conditions to be imposed is the safety of electrical installations in operation, ie continuous supply of electricity to consumers.

Ensuring the uninterrupted operation of electrical installations is very important, because the consequences of disturbances in function can be very serious, but also because the electrical installations are more likely exposed to damages than other types of equipment.

The seriousness of the consequences derived primarily from the fact that:

- electrical installations, in general, are parts of a energetic system complex and are inter-connected electrically;
- a defect occurred in a place mind the whole system normal functioning; and secondly, the severity of defects in electrical installations is due to very high energies involved in their conduct, leading to extremely high destructive effects.[7], [8].

The main role of automation and protection through relays used in electric power systems was to limit the occured effects of damage and to ensure uninterrupted electricity supply to consumers.

To achieve these two fundamental functions, protection devices, regardless of type or constructive principle is based, must meet the following general conditions:

- selectivity, that is to disconnect only the damaged item and allowing further function of undamaged plants;
- sensitivity, that is notification of all defects and abnormal operating regimes, even when they differ only slightly from normal operating conditions of plants;
- speed, which is necessary that only a quick disconnection of damaged items can remain without consequences on the functioning of undamaged plants;
- reliability, which consists in that the relay protection devices, which rarely works (several times a year), must be prepared, even after a long period of rest to work.[9], [10], [12].

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