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# PARAMETRIC-ACTIVE COMPENSATION OF EARTH FAULT CURRENT IN AN IT-TYPE NETWORK*

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**Abstract:** The parametric-active compensation of earth leakage currents which minimalized virtual capacitance current in ships of IT-type network has been discussed. The protection is based on automatic compensation of leakage earth currents. The protection system is governed by a controller. The results of simulation tests have been presented. The parametric-active compensation of earth leakage currents which minimalized virtual capacitance current in ships with IT-type network has been discussed.

**Keywords:** *IT-type networks, earth currents, fault current compensation*

## 1. INTRODUCTION

Nowadays electric devices operated on board ships are supplied from 3-phase AC networks with insulated neutral point (IT-type networks). Within networks of such type considerable hazards of shock as well as of explosion and fire as a consequence of earth fault exist. Despite the fact that such networks were introduced several decades before, the protection methods have not been improved. The paper describes hazards existing in such networks and some possibilities to increase the safety of their operation.

## 2. COMPENSATION OF EARTH FAULT CURRENTS IN IT-TYPE SHIO NETWORKS

For many years on the vessels with IT-type electrical network a problem of the limitation of leakage currents occurred [1–5]. Because of using lots of long cables, the IT

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electrical nets have some earth capacitance. In spite of touching one phase, earth capacitance currents can cause electrical shock. Despite the fact that such networks were introduced several decades ago, the protection methods have not been improved.

Values of shock currents and levels of fire and explosion currents are shown in Fig. 1 [1] where Fire is an area without compensation of earth currents, while the Smoke area is that of flammable dust and an Expl. is the area of danger if explosion. Curve 3 corresponds to the highest values of safe shock currents $I_{hb}$ according to IEC rules [2, 5].

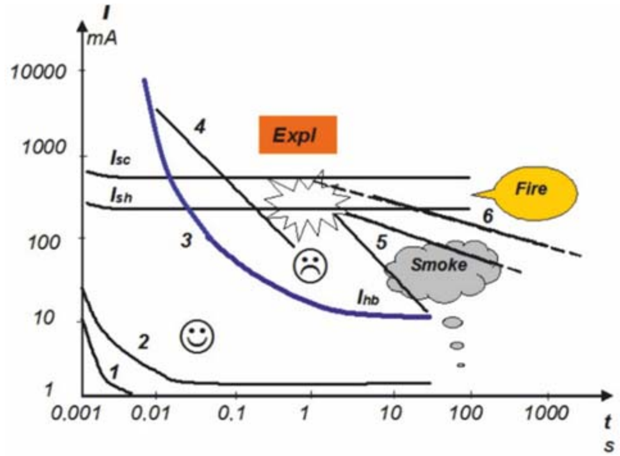


Fig. 1. Effects of leakage currents in IT-type ship's network:
$I_{sc}$ – phase short-circuit current, $I_{sh}$ – shock hazard current, $I_{hb}$ (curve 3) – safe shock current; curve 1 – compensated shock hazard, curve 2 – compensated short-circuit current, line 4 – border of spark explosion current, lines 5 – current area for smoke of flammable dust, line 6 – border of fire area

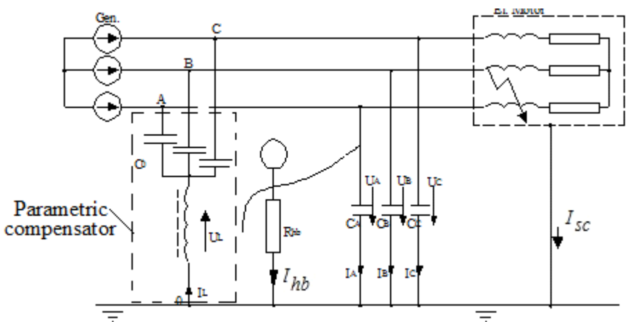


Fig. 2. Ship's IT-type Network with parametric compensator

Researchers from the Maritime Academy in Szczecin for many years conducted studies on the construction of a device for compensation of fault currents. These activities led to the development of various such devices. Initially, the project design was based on installing a line choke between the hull and the artificial neutral point. Such an idea was implemented in 1984 at the Institute of Marine Automation and Electrical Engineering [6]. Figure 2 shows the practical realization of this idea and the paths of changed current flows [6, 10–12, 14] through distributed capacitances. In practice, implementing of the solution was possible in the preliminary stages by connecting additional lumped capacitance. A description of this scheme and analysis have been presented in detail elsewhere [10, 12]. The system has resonance currents at the frequency of 50 Hz. However, a slight asymmetry of capacitance currents leads to a sharp increase in the current of the faulty phase and the risk of fire or explosion [10].

## 3. COMPENSATOR WITH THE IMPEDANCE CONVERTER IN IT-TYPE SHIP NETWORKS

Nowadays electric devices operated in order to reduce the current of the faulty phase led to the creation of the compensator with the impedance converter of the UKPP-2 type (Fig. 3). A network with an impedance converter is a system with a positive feedback.

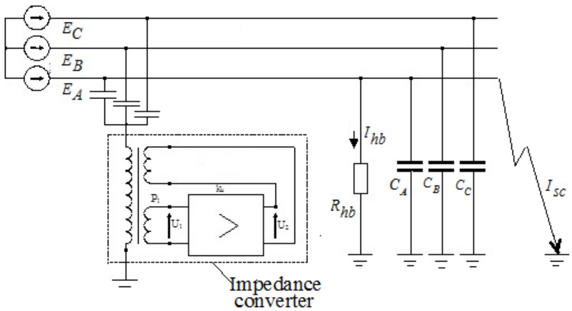


Fig. 3. Compensation unit of impedance converter

System with the UKPP- 2 has been implemented at 30 ships of the Polish Navy. The above solutions are satisfactory when the distributed capacitances are symmetrical and network parameters are constant [6–11].

## 4. COMPENSATION WITH ACTIVE CONVERTERS IN IT-TYPE SHIP NETWORKS

To compensate changes in network parameters, a device for voltage active compensation has been developed. Such a compensation network is shown in Fig. 4 [15–25]. The signals from the phase voltage controlled by the source of compensating voltage sensors are supplied to a logic unit which determines the faulty phase.

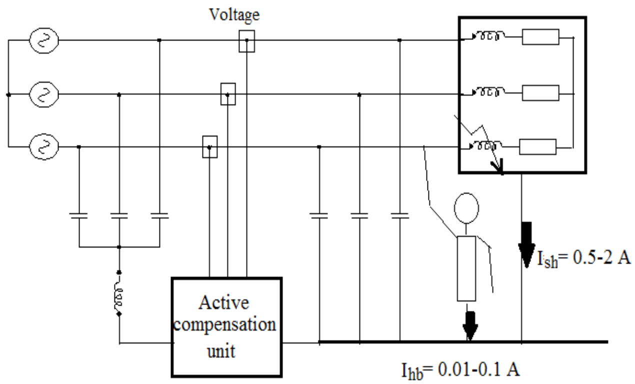


Fig. 4. The voltage active compensator of ship's IT type network

A logic block has been constructed based on the neural network and implemented to PC. This solution required considerable software and hardware resources [15, 20–25]. For a dedicated electric circuit with a leakage current transformer, an active compensator has been designed on the basis of a single-phase current inverter. The idea of the method of compensation using a current source is shown in Fig. 5. The active compensator is controlled by a signal from the current sensor.

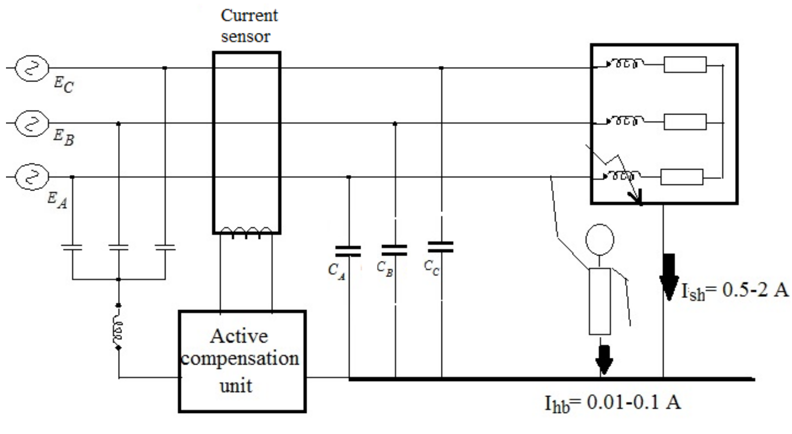


Fig. 5. The current active compensator of a ship's IT-type network

Active compensator using current source does not require a logical block. Application of this compensator can simplify the control circuit and reduce the fault current in a network of IT-type [26–29]. The results of tests for all solutions are presented in Fig. 6. The short-circuit currents of the symmertical netwoks are shown in the left hand side of the picture, those of the asymmertical netwoks – in the right hand side. The survey showed that the only possibility is the use of the current active compensator in ship's network of IT-type.

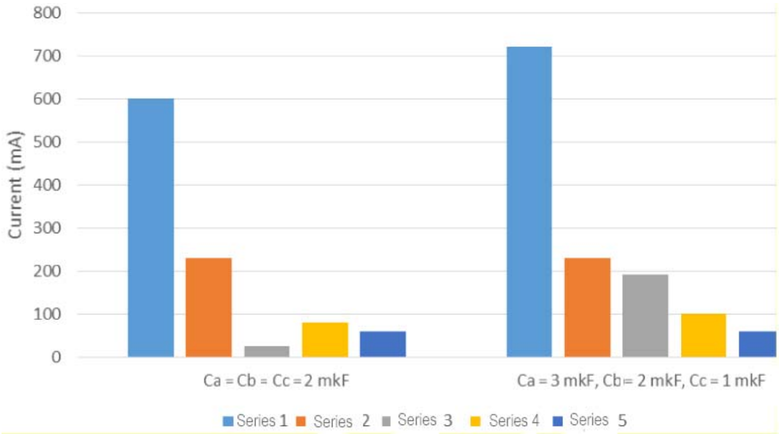


Fig. 6. Effect pf compensation earth currents of IT-type network by resistance $R_{sh}$ = 5 Ω; Series 1 – without compensator's, Series 2 – the parametric compensator, Series 3 – the impedance converter, Series 4 – the active voltage compensator, Series 5 – the current active compensator

In addition to compensation of earth currents of one of phase, we have also compensation current of human body. In Figure 7, the current of human body ($R_{hb}$ = 1000 Ω) for connecting to one of phases is presented.

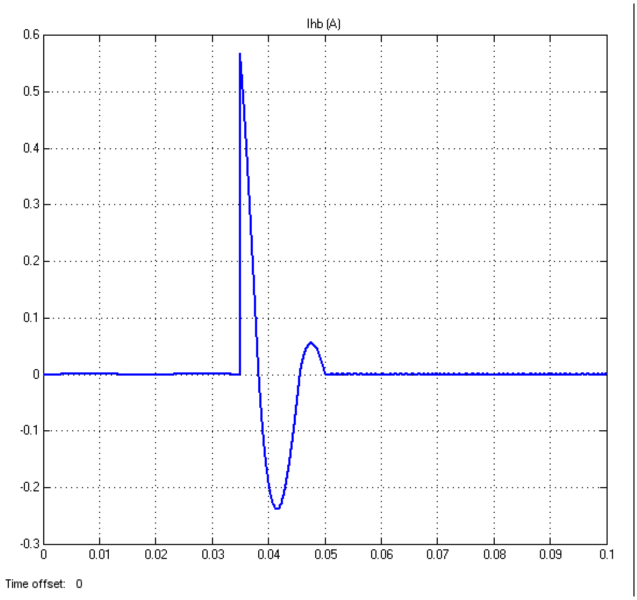


Fig. 7. The current of human body of ship's IT-type asymmetric network

Ampere second area during the transition process lies below curve 3 (Fig. 1). Thus active compensation allows one to save the ship from the fire and humans from electric shock.

## 5. CONCLUSIONS

- Compensation of the faulty phase current in the IT-type network is possible; the method presented meets IEC rules.
- The current active compensator presented in this paper is ready for industrial applications.
- A developed method of parametric-active compensation enables one to protect both the humans and the ship at major changes of earth fault parameters and frequency.
- Basing on the carried out analysis, a new practical solution of problems connected with compensation of earth fault currents in IT-type networks has been suggested.

## REFERENCES

[1] HRYNKIEWICZ J., CZERNECKI L., ZELUDIEWICZ R., *Compensation short-circuit currents and currents of human in ship's electric networks*, Research Materials of the WSM Szczecin, 1979–1998.

[2] *Effects of current passing through the human body*, Publication 479-1 IEC, Geneve 1984.

[3] NIKIFOROVSKY N., BRUNAV J., TATIANENKO Y., *Electrical and fire protection of the ship's electrical systems*, Shipbuilding, Leningrad 1978.

[4] The International Maritime Organization – IMO, *International convention for the safety of the state of life at sea*, Solas, 1998.

[5] *Polish register of shipping rules for classification and construction of ships*, Vol. 8, *Electrical equipment and automation*, Polish Register of Ships, Gdańsk 1995.

[6] CZERNECKI L., HRYNKIEWICZ J., A certificate of copyright No. 247203 patent # 146510 (28.11.1989). *Method and equipment for compensation of active and capacitive currents*, Int CL4 H02H 9/08.

[7] *Compensation system of the capacitive current UKPP-2*, Technical documentation I-207-160, Telzas, sp. z o.o., Szczecinek 1995.

[8] LR Type Approval Certificate No. 88/0348(E1)1993-98, *Capacitive earth fault current compensator UKPP-2 Type*, Telzas, sp. z o.o., Szczecinek 1995.

[9] *TUK-02 Type Tester for the UKPP-2*, EPS Szczecin 1994, PRS approved 1995.03.21.

[10] HRYNKIEWICZ J., *Leakage current compensating systems within electroenergetic network on board the Polonia ferry SEE-99 Crimea*, Ukrainian Academy of Sciences Press, Kiev 1999.

[11] GERMAN-GALKIN S., HRYNKIEWICZ J., ZELUDIEWICZ R., *System parametric-active compensation of earth currents in IT* systems, Patent RP #188584 (5.05.2005).

[12] MUSIAŁ E., JABLONSKY V., *The technical conditions which must comply with the low voltage electrical equipment in the field of fire protection*, Newsletter SEP INPE Electrical Standards and Regulations, 1999 (24), 3–56.

[13] GERMAN-GALKIN S., HRYNKIEWICZ J., *Compensation of earth fault currents in IT-type ship networks*, International Conference PCIM 2000 Germany, Nurenburg 2000.

[14] GERMAN-GALKIN S., HRYNKIEWICZ J., *Influence of harmonics on the compensation of the capacitance currents in IT networks*, 7 International Conference Engineering and Technosphere on the Turn of the Century, Sevastopol, 12–17.09.2000.
[15] GERMAN-GALKIN S., HRYNKIEWICZ J., *Method and equipment to identify the damaged phase in IT network*, Patent RP#189863 (21.09.2005).
[16] GERMAN-GALKIN S., HRYNKIEWICZ J., *Analysis of human and vehicle protection devices in terms of damage to electrical networks*, Conference StPSPI, St. Petersburg 2000.
[17] GERMAN-GALKIN S., HRYNKIEWICZ J., *Analysis of compensating devices in electric network of type IT*, Conerence SEE, Frunze 2000, 4.
[18] GERMAN-GALKIN S., HRYNKIEWICZ J., *System of compensation currents damage in marine electrical networks*, Bulletin of the Kharkov State Technical University, a series *Electrical Engineering, Electronics and Electric Drives*, Ed. 113, Kharkiv 2000, 164–166.
[19] GERMAN-GALKIN S., HRYNKIEWICZ J., KOZAK M., *Protection of people and vessels from the damage of the electrical ship, s network*, Conference EPiF 2000, Szczecin 2000, 5.
[20] GERMAN-GALKIN S., HRYNKIEWICZ J., EMYELYANOV A., KOZYARUK A., *Computer-technology design of compensation systems in the ship's electric network*, *Technical Electrodynamics*, Series *Power Electronics and Energy-Efficiency of H2*, Kiev 2001.
[21] GERMAN-GALKIN S., HRYNKIEWICZ J., *The application of computer technology in the design of ship IT systems*, Sci. Techn. Conference SENE 2001, Łódź 2001.
[22] GERMAN-GALKIN S., HRYNKIEWICZ J., *Computer technology research and designing compensators capacitive currents in ship electric network*, Scientific works KGTU 2001, 45–54.
[23] GERMAN-GALKIN S., HRYNKIEWICZ J., *Neural networks for identification of damage in ship's power system*, EXPLO-SHIP 2002, 4.
[24] GERMAN-GALKIN S., *Planning experiment in the forming of DATABASE for neural networks in the analysis of damage to the ship's power system*, *Technical Electrodynamic*, Series *Power Electronics and Energy Efficiency*, Vol. 3, Kiev 2002, 6.
[25] GERMAN-GALKIN S., *Identification of damage phase in the ship's electrical network*, International Scientific-Technical Conference Balttehmash 2002, Technical University, Kaliningrad 2002, 4.
[26] GERMAN-GALKIN S., HRYNKIEWICZ J., *The compensating system in ship power systems*, Proc. International Conference Analysis, Forecasting and Control in Complex Systems, Academy of Sciences of Russia, St. Petersburg 2005, 156–175.
[27] PN-HD 60364-4-41. *Protection for safety*, Polish standards, Warsaw 2009.
[28] GERMAN-GALKIN S., HRYNKIEWICZ J., ZELUDIEWICZ R., *Reducing the fire hazard and safe shock current in IT ship networks*, News Electrotechnical, 2011 (1), 38–42.
[29] MUSIAŁ E., *Protection safe shock current in low-voltage devices. The consequences of the establishment of the standard PN-HD 60364-4-41:2009*, *Monthly SEP information about the electrical standards and regulations – INPE*, 2010 (129–130), 5–39.