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The intelligent fault detection system of underwater vehicle electrical devices

Abstract. *The structure of a fault control block as a part of an intelligent fault detection system is developed. The structure of a fault control program as a part of an intelligent fault detection system based on artificial neural network is developed. In case of fault detection the intelligent fault detection system can de-energize the controlled electrotechnical device, which prevents its damage.*

Keywords: remotely operated vehicle, electrical device, fault detection, artificial intelligence

Underwater vehicles and systems pertain to basic techware and are widely applied within underwater tasks fulfillment where divers involvement is not reasonable, complicated or hazardous. Wide task list can be performed with tethered underwater system (TUS) equipped with multifunctional self-propelled remotely operated vehicle (ROV) [1].

The peculiarity of compact class ROVs (<150 kg) is that almost all of its equipment is represented in electrotechnical devices (high- or low-voltage and current) of a different complexity level that function underwater in extreme for electrical equipment conditions.

The most critical to ROV electrical devices functioning is water leakage into their hulls which causes equipment malfunctioning and failure. Also there is a possibility of other incidents such as propeller jamming as a result of seaweed wrap, small stones hit into gap between propeller and its nozzle etc. Timely detection of propeller jamming, firm hulls water leakage, pressure relieved hulls water influx and other operating irregularities gives an opportunity to avoid many unwanted consequences, locate point of fault, quickly eliminate fault cause and continue task performing. That is why modern TUSs need integration of a fault detection systems (FDS) able to perform diagnostics on-the-fly with ROV electrical equipment.

Let's cite the ROV "Inspector" (National University of Shipbuilding, Ukraine) as an example. Its basic electrotechnical equipment includes electrically driven thrusters (EDT), high- and low-power electronics installed within firm hulls, spot- and diffuse lanterns and videocamera (fig. 1).

All the ROV elements are installed on a carrying frame and are held in water mass due to a foam buoyancy. The sonar and manipulator are also shown on fig. 1 as an example of attached equipment.

The FDS integration consists in fault control blocks (FCB) installation into ROV`s electrical devices power circuits and a fault control program (FCP) installation into ROV`s control software. Every FCB contains voltage (V) and current (A) sensor and a controlled circuit breaker that is activated on demand, so the FCP is able to monitor an electrical device functioning by indirect signs and de-energize it in case of emergency which prevents its damage.
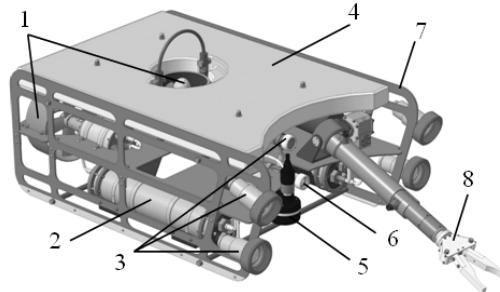
Figure 1. ROV components: 1 – EDTs, 2 – firm hull,
3 – lanterns, 4 – foam buoyancy, 5 – sonar,
6 – videocamera, 7 – carrying frame, 8 – manipulator.

To satisfy modularity approaches requirements of ROV design [2] it is proposed to standardize FCB and realize it in accordance to the block diagram, presented on fig. 2.
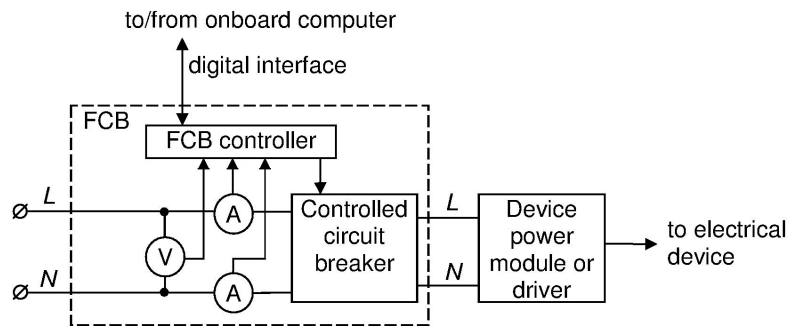

Figure 2. Fault control block structure.

Every onboard electrical device is equipped with an appropriate power module or driver. For example LED-lanterns are supplied by constant current sources, luminescent lanterns are supplied by specialized start-up and control gears, asynchronous motors are supplied by controlled frequency converters, navigation and other low-power devices are supplied by AC-DC-converters. At the same time every power module or driver is powered by onboard power network which has standard parameters, for ROV "Inspector" it is AC 220V 50 Hz.

The FCB task is to perform continuous measurement of a power module voltage and current and send monitoring data (upload flow) to FCP by means of onboard computer. Amperemeters usage in phase (L) and neutral (N) lines gives an opportunity to reveal current leakage by principles of protective cutout devices.

The FCP in turn analyses received data and if the deviations are detected sends a command to FCB (download flow) to de-energize the controlled power module as well informs operator about detected fault. All the information flows are performed by means of digital interface.

While working by such algorithm the FCB doesn't make any decisions and is a typical device for almost all ROV equipment. All the decisions makes FCP which monitors every electrotechnical device functioning.

For correct FCP working it has to be preliminary adjusted. So far as power consumption is able to change even of devices that have only to states (on/off) for example as a result of its element heating, it is proposed to build the FCP with artificial intelligence components – neural network (NN) software implementation, and to perform its training to proper device operation – master electrotechnical data (fig. 3).
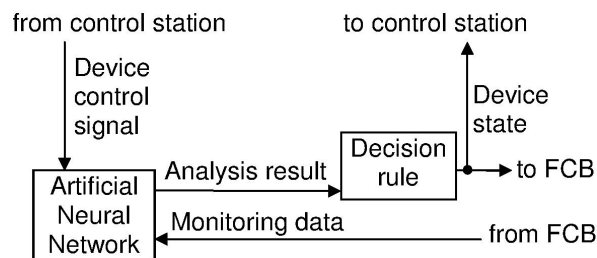
Figure 3. Fault detection system intelligent component within FCP.

The trained NN receives monitoring data from FCB, analyses it and outputs the result, the decision rule block makes the final decision and generates the device state – the signal which can take two states: normal device functioning and device malfunction.

The FCP should include such intelligent component for every ROV electrotechnical device. The intelligent component sends device state to FCB and to control station to inform an operator. The proposed structure also satisfies the modularity approaches requirements of ROV design stated in [2].

The most complex is an intelligent component adjustment to proper operation of devices which power consumption could dynamically change within wide range during ROV operation. Such changes first of all depend on device control signal as well on external disturbances exposure.

On the ROV "Inspector" such devices are electromotors of EDT. To form the master electrotechnical data it is necessary to perform certain positioning and high-speed maneuvers including control signals to master data.

The presented approaches are proposed to use not only within TUSs but within other types of underwater technics including autonomous underwater vehicles.

Conclusions
1. The basic elements of small-sized remotely operated underwater vehicles are singled out, it is shown that almost all elements are presented in electrotechical devices which function in extreme conditions and need to be monitored continuously.
2. The structure of a fault control block as a part of an intelligent fault detection system is developed. The fault control block makes possible to measure basic electrotechical parameters of an underwater vehicle device and to send the monitoring data to the fault control program. In case of fault detection it can de-energize the controlled electrotechnical device, which prevents its damage.

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3. The structure of a fault control program as a part of an intelligent fault detection system based on an artificial neural network is developed. The intelligent program component analyses device's monitoring data, compares it with master data and in case of deviation detection sends a command to the fault control block to de-energize the controlled device and informs an operator about detected fault.

Literature

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