SMAIC

STATE MARINE ACCIDENT INVESTIGATION COMMISSION

FINAL REPORT

41/19

Very serious marine casualty

of a fishing cutter *JAS - 57 Magdalena*

Death of a crew member due to electric shock

April 2020

The examination of a very serious marine casualty of the death of a crew member of a fish cutter vessel *JAS-57 Magdalena* was conducted under the State Marine Accident Investigation Commission Act of 31 August 2012 (The Journal of Laws of 2019 item 1374) as well as norms, standards and recommended procedures agreed within the International Maritime Organization (IMO) and binding the Republic of Poland.

The objective of the investigation of a marine casualty or incident under the above-mentioned Act is to ascertain its causes and circumstances to prevent future casualties and incidents and improve the state of marine safety.

The State Marine Accident Investigation Commission does not determine liability nor apportion blame to persons involved in the marine casualty or incident.

This report shall be inadmissible in any judicial or other proceedings whose purpose is to attribute blame or liability for the accident referred to in the report (Art. 40.2 of the State Marine Accident Investigation Commission Act).

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1. Facts

On 28.05.2019 at 22:30 a fish cutter *JAS 57 Magdalena* with four crew members moored at the Duńskie wharf in the port of Władysławowo. There were 30 boxes of cod in the hold. Since it was planned that the fish would be unloaded the next day at noon, the decision was made to switch on the cooling system of the hold. The 400 V shore power supply was connected from the power box at the wharf, however the cutter could not be powered due to the operation of the residual power circuit breaker (RCCB). The attempt to connect the converter with 230 V current directly from the power box at the wharf using an extension cord, ended up with the electric shock suffered by the motorman. Despite immediate resuscitation that lasted for over an hour, the victim could not be saved. On 29.05.2019 at 01:12 the doctor pronounced the motorman dead.

On 11 July 2019, the Commission received information about a similar event that took place on the *JAS 57 Magdalena* cutter in the port of Jastarnia. While attempting to connect the converter directly to the power supply using an extension cord, the cutter's skipper was given an electric shock. The injury caused only a short painful contraction of the forearm muscles. [1]

The causes of the electric shock were the same in both cases and therefore they are described in one report.

2. General Information

[1] The instance of electric shock on board the *JAS 57 Magdalena* cutter on 11 July 2019 was registered in the SMAIC casualty database under the number WIM 72/19.

Photograph 1: Fish cutter, „JAS 57 Magdalena"

2.1. Ship Particulars

Vessel's name:	*JAS – 57 Magdalena*
Flag:	Polish
Year of built:	1965/2017
Shipyard:	Repair Shipyard of Szczecin
Owner:	private individual
Operator:	private individual
Classification society:	PRS S.A.
Vessel's type:	fish cutter
Call signal:	SPG 2599
Gross tonnage (GT):	40
Length overall:	20.60 m
Width:	5.20 m
Draught:	2.13 m
Power:	448 kW (Caterpillar Inc., 1/3176) limited to 265 kW
Hull material:	steel
Minimum crew:	3

2.2. Voyage Particulars

Port:	Władysławowo
Type of navigation:	stop at port
Information about cargo (quantity, kind):	30 boxes of cod in the hold
Information about the crew (number, nationality):	4 Poles
Information about passengers (number, nationality):	no passengers

2.3. Accident Information

Kind:	very serious marine casualty
Date and time of event:	29.05.2019 at 00:05[2] LT
Geographical position during the event:	the port of Władysławowo
Geographical area of the event:	the port of Władysławowo, the Baltic Sea
Nature of the water region:	port waters
Weather during the event:	lack of waving, wind direction W – 4ºB, good visibility, ambient temperature + 12ºC
Operational status of the vessel during the accident:	stop at the wharf
Place of the accident on board:	main deck, starboard side exit from the superstructure
Effects of the accident:	electrocution of a crew member

2.4. Shore Services and Rescue Action Information

The electrician of the energy service of the Szkuner company at 00:05 notified the administrator of the port (Serwis Szkuner) about the accident on board *JAS 57* and the need to call an ambulance. This information was forwarded on VHF channel 10 to the port boatswain, who called the ambulance. The information about the accident obtained from radio watch on the *Bryza* rescue vessel was forwarded to the Maritime Rescue Coordination Center in Gdynia. MRCK ordered the Shore Rescue Service in Władysławowo to go to the site and provide help. The Emergency Medical Team called by the boatswain the port of Władysławowo arrived at the

[2] Time of events is local time (LT)

site at ca. 00:15 and started cardiopulmonary resuscitation of the injured, replacing crew members who had been resuscitating the victim until that time. the Shore Rescue Service of Władysławowo, approached the cutter and joined the rescue operation supporting the rescuers. At. 00:51 another Emergency Medical Team came to the wharf with a doctor who at 1:12 pronounced the motorman to be dead.

3. Circumstances of the Accident

On 28 May 28 2019 at 22:30 the cutter, *JAS 57 Magdalena* with a crew of four entered the port of Władysławowo and moored starboard side to the Duńskie wharf. There were 30 boxes of cod in the hold, which were to be unloaded in Władysławowo. After receiving information that the cod would be delivered at noon the next day, the operator, who was also a member of the crew that day, and the skipper decided to switch on the cooling system of the hold. To connect the 400V power supply from the shore, a cable was delivered to the cutter's side by a motorman who came from Jastarnia for this purpose. In the meantime, while waiting for the power supply cable, the crew cleaned up the deck of the cutter and then the deck and sheets[3] of the superstructure were rinsed with fresh water. When the cable was connected to the power supply box at the wharf and to the socket located in the fore part of the cutter's superstructure, no power was found. The electrician on duty from the Szkuner company checked the cause of the lack of power and informed the cutter's crew that it was due to the activation of the residual current circuit breaker (RCCB). Several attempts to supply power from the shore were unsuccessful because each time the RCCB was activating. Despite the lack of shore power, the compartments and decks were illuminated since the power was supplied from the battery and the ship's converter. After a series of unsuccessful attempts to connect power from the shore, the skipper and the operator decided that they would go home to rest and would return in the morning to put the fish on ice. While preparing to leave the vessel they were at the bridge while the motorman went to the engine room, connected the two-wire extension cord to the converter's power cable and, with rolled up extension cord, went to the deck to connect it to the 230 V power socket in the box at the wharf. At the same time, the electrician from the Szkuner company, with the power cable connected to the vessel, closed and secured the power box. At ca. 00:05 on 29 May 2019, there was a loud scream and the electrician heard a sound from the deck of the cutter as if someone falling. From his position he could not see the deck covered by the bulwark.

[3] Side walls of the superstructure

Figure 1: The place where the victim fell on deck

Hearing the scream, the crew members at the bridge ran out onto the deck and noticed the motorman lying between the superstructure and the side at the exit of the engine room. The victim was holding a coil of the extension cord. The operator snatched the cord from the victim's hands and dumped on the deck. The skipper, seeing at first the signs of losing breath and consciousness and then the lack of breath and heartbeat, began to resuscitate the motorman. The operator instructed the electrician to call for help, and joined the resuscitation himself. The emergency medical team arrived after about 10 minutes and took over the rescue of the victim. SAR members joined the life-saving action supporting the ambulance rescuers. At 01:12 the doctor declared the motorman to be dead.

4. Analysis and Comments about Factors Causing the Accident with Regard to Examination Findings and Expert Opinions

JAS 57 Magdalena is a fish cutter of the STOREM 4 B type that was built in 1965 in the Szczecin Repair Shipyard. In the years 2016-2017 there took place a significant reconstruction of

the vessel, including partial exchange of the superstructure from steel to aluminum and significant reconstruction of the after deck.

Photograph 2: Reconstruction of the cutter, JAS 57 in 2016 (author: A. Dubowicz)

Photograph 3: Exchange of the superstructure on the cutter, JAS 57

During reconstruction, the electrical installation on the cutter was changed, including a new converter. The description of the electric installation of the cutter is provided in Annex 1. The cutter was operated for most of the year as a vessel for fishing and during fishing breaks in the summer, it was used to transport passengers in the waters of the Gulf of Gdańsk. On 11 July 2019, after the day of transporting passengers on the Jastarnia - Hel - Jastarnia route was over and the cutter was moored at its regular, permanent berth in the port of Jastarnia, the skipper intended to connect the electric power supply of the cutter to the power terminal connection available at the wharf by means of a retractable extension cord with a single-phase cable (2x1 mm^2) with a plug on one side and a set of four sockets on the other. After leaving the engine room with the cable, he was given an electric shock. The skipper managed to throw the cable away on the deck, getting rid of the source of the shock. The detailed course of events is included in Annex 2. Due to the fact that in both cases the electric shock resulted from attempting to connect the shore power supply directly through the converter, the Commission decided to dismount the converter from the cutter and examine it. The description of the converter and the results of examinations are presented in Annex 3.

4.1. Mechanical Factors

When analyzing the causes of the accidents, the first step was to assess the condition of the extension cords that were used in both cases with the intention of connecting the converter directly to the 230V 50Hz power socket on the shore. The results of the assessment stated that the above-mentioned connection cords were in good condition and they were not the cause of electric shock for both victims.

After removing the Power Sinus 3000 24V converter from the vessel, it was examined in conditions similar to those prevailing on the cutter, with regard to their ability to generate dangerous voltage on the housing or clamps giving an electric shock to a crew member. The results of the examination clearly showed that it was not possible. At the same time, the Commission found that the converter was not properly grounded and it was installed in a room that did not meet the requirements specified in the User's Manual of the device, and the device itself did not meet the requirements of the classifier and as such should not be have been installed on the side of the vessel.

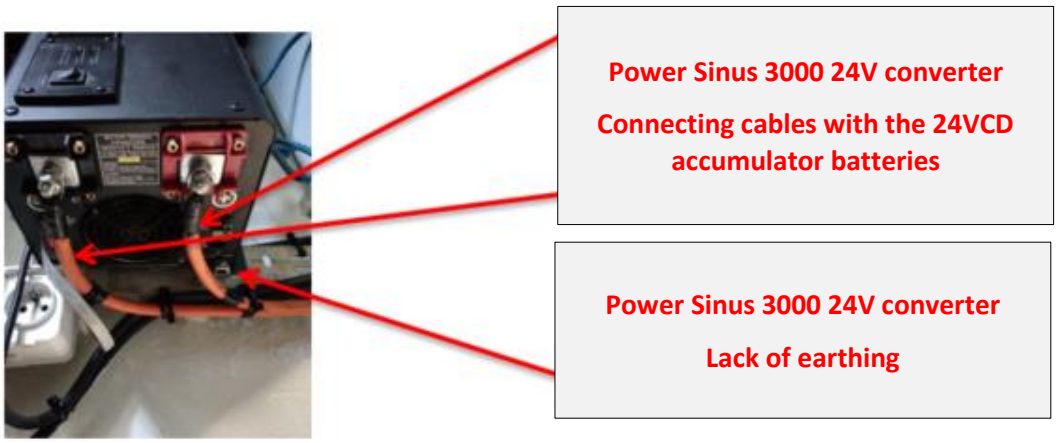


Figure 2: Connection of accumulator batteries with the converter

The arrangement of the components of the electrical system allowed errors and mistakes to be made during its operation. This was due to the lack of current drawings/connection diagrams of the electrical installation components. Part of the wiring was not permanently attached. There were deficiencies in unambiguous marking and description of the purpose of electrical circuit components. Electrical sockets with different electrical parameters (230VAC/ 24VDC) were of the same type. Installation of the converter, apart from the lack of earthing made it possible to access electrically conductive parts. Therefore, the protection of electrical circuits against direct contact was not ensured.

The electrical installation was not made in accordance with the norm PN-HD 60364-4-41:2009 concerning low voltage electrical installations, protection to ensure safety and protection against electric shock.

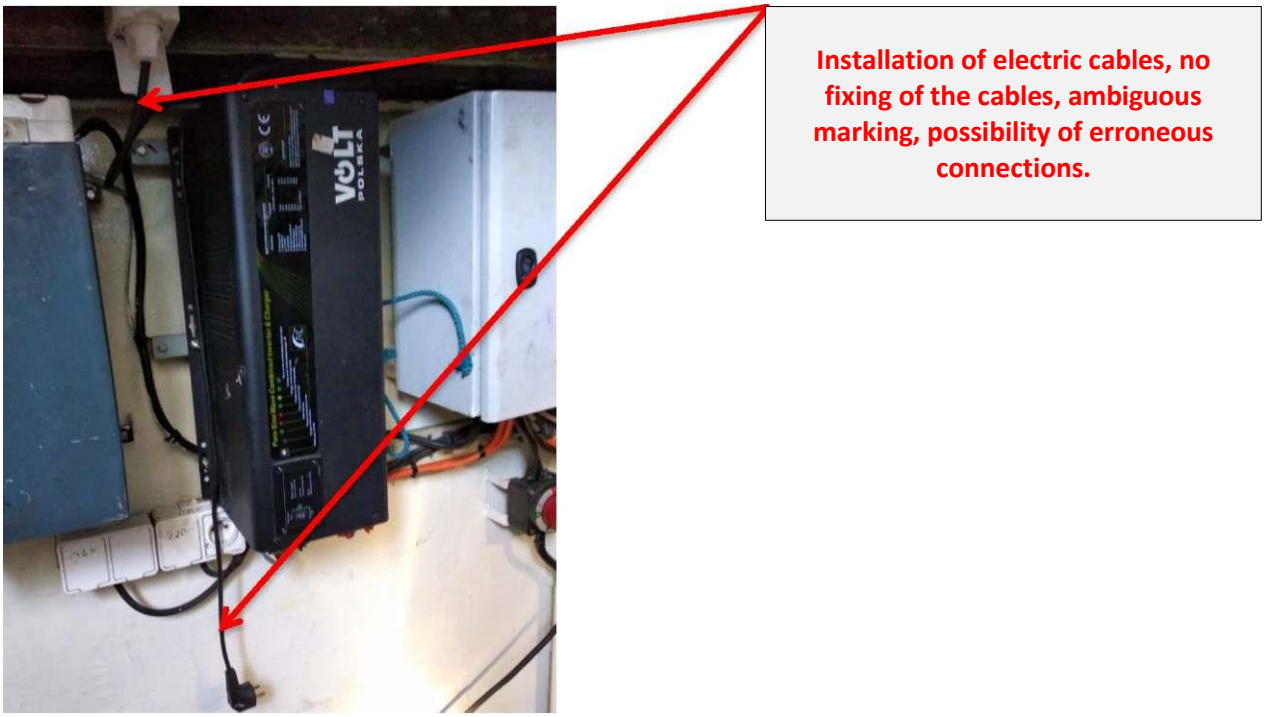


Figure 3: Instalation of electric cords

Figure 4: Installation of electric sockets 24VDC i 230VAC

In the opinion of the Commission, one of the key factors in the investigated casualty was the state of insulation of the cutter's electrical installation. Consistent information of all witnesses confirms that several attempts to switch on the 440V 50Hz power supply from the shore in Władysławowo were unsuccessful due to the operation of the RCCB. At that time it was assumed that the reduction of insulation resistance applies only to the installation of the cooling system. In fact, there were other places indicating the possibility of reducing the state of insulation of the installation. Incorrect installation of a fluorescent lamp could be an example.

Photograph 4: Switchgear of the cold store

Photograph 5: Fluorescent lamp

4.2. Human Factors

The victim had held a valid motorman's certificate since 2011 and a valid certificate of a senior sea fisherman since 2017. He was authorized, among others, to operate electrical equipment located on the cutter, including connection of power from the shore. An important element related to the preparation for servicing electrical installations is the fact that the training program in electrical engineering and ship electronics for the motorman[4] includes 7 hours of lectures, including the principles of safe work with electrical equipment on board.

[4] Annex No 1 to the Order of the Minister of Infrastructure and Development concerning the Training Program Framework and Examination Requirements for Seamen of the Engine Department (i.e. Journal of Laws: Dz.U. of 2017 item 775)

On the day of the accident, due to the malaise, the motorman remained at home and did not participate in fishing. To help the crew run the cooling system of the hold, he came from Jastarnia to Władysławowo to connect power supply to the cutter with a power cable. An additional factor was the rush resulting from late hour and unsuccessful attempt to connect the cutter's power supply to a 400V 50Hz power supply from the power connection at the wharf.

4.3. Organizational Factors

The supervision of the classification society over the reconstruction of the cutter in the scope of performed electrical works was limited to accepting the statement of the contractor of these works, having valid PRS qualifications, on reassembly of the electrical installation without changes, despite the replacement of wiring, devices and changes in the connection system. The contractor did not prepare a scheme of significant changes to the electrical installation on board the cutter and did not submit it for assessment and approval by the classifier, despite such a requirement included in the PRS regulations. Thus, it deprived the classifier of the possibility to react early enough to any possible errors in the electrical installation.

Neither the operator nor the skipper or the classifier received electrical diagrams of the electrical system installed after the reconstruction of the superstructure. The contractor did not prepare a manual for safe operation of the installed converter.

Detailed analysis of the cutter's power supply, in particular of the method of connecting power from the shore has indicated that the accident would not have happened if the crew connected power supply of the vessel only through a socket dedicated to the shore power supply. Then, the positions of switches, constituting the excess current protection of the power supply circuits and take-up of electricity, would be in such positions that they would galvanically disconnect the 230VAC load from the output circuit of the converter. The unloaded converter would not go into inverter operation, it would not generate 230V, which even in case of its damage would not give electric shock to *JAS 57* crew members.

4.4. Influence of External Factors on the Accident, Including Factors Related to the Marine Environment

The accident took place while the vessel was at port, moored to the wharf. The cutter's quarters and decks were well illuminated. One of the factors that were related to the accident was a wet deck and a superstructure and a wet mat lying at the exit from the engine room to the deck with

the purpose of protecting people leaving the superstructure from slipping. An additional factor was the late hour for performing connection work.

5. Description of Examination Findings Including the Identification of Safety Issues and Conclusions

5.1. Description of the Course of the Accident

The Commission determined the following course of the electrocution of the motorman on board the *JAS 57* cutter illustrated in Figure 1.

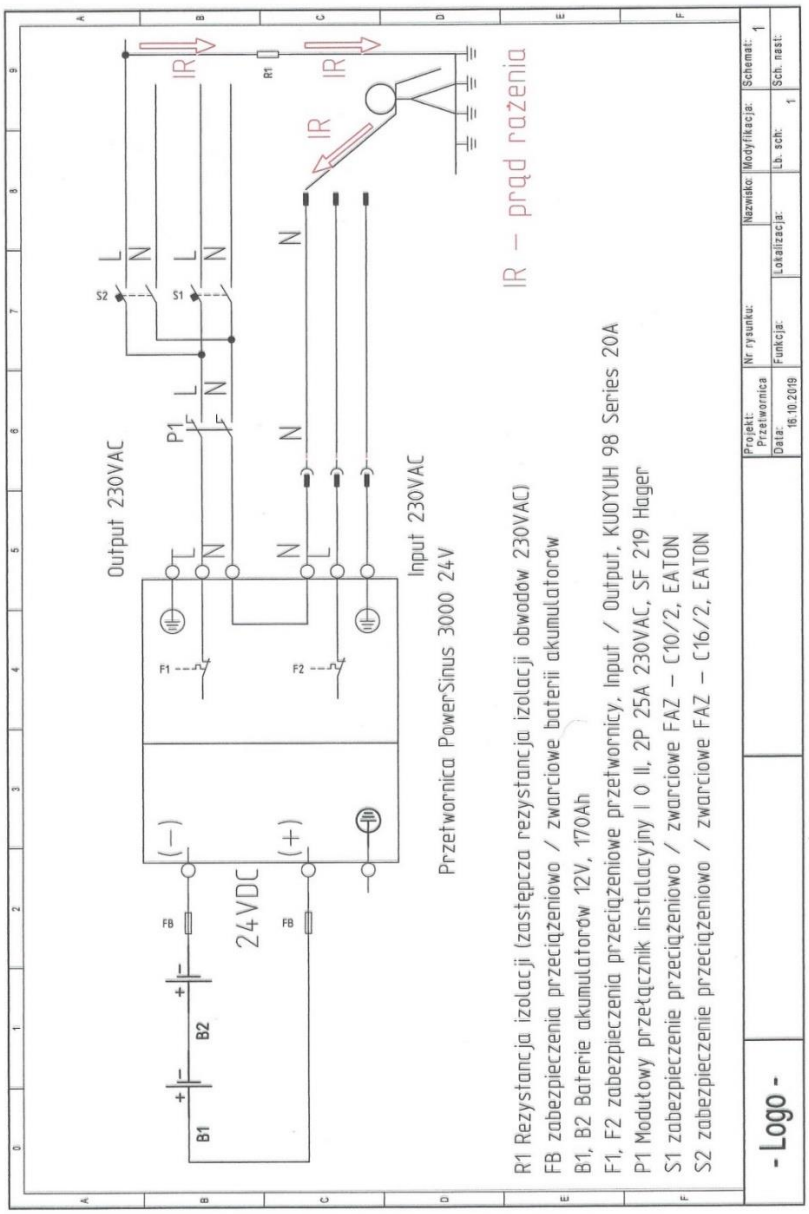


Figure 5: Electrocution of the crew member – a schematic diagram

Since it was impossible to provide power supply from the shore using a dedicated power cable connected to the 400V power outlet at the wharf, the victim attempted to use a direct connection for 230V power supply from the shore to the ship's converter.

After switching on (intentionally or accidentally) the converter to work in the Power Saver Off mode, by switching the switch on the converter's housing or switching the switch on the LCD panel located on the cutter's bridge, the converter started working in the inverted mode. It has properly generated voltage at its 230V, 50Hz output terminals (Output 230V). The 230V power supply selection switch on the bridge that was turned on to the converter position (Figure 9) caused the supply of power to the damaged 230V circuits. Damaged insulation of electrical circuits caused the appearance of phase voltage marked "L" on the steel-aluminum structure of the cutter.

At the same time, the crew member was carrying a cable connected to the converter's input terminals. After leaving the engine room, he touched with his hand one of the poles of the plug, the unshielded pin of the plug connected to the converter's "N" terminal. During this time he was standing on a wet mat lying on board in front of the exit from the engine room. Damaged insulation of the electric system of the cutter caused that the crew member suffered an electric shock.

The electric current flew through the victim's body as presented in the diagram. The value of the IR current that flew through the victim's body resulted from full AC voltage generated by the converter (230V, 50Hz), R1 insulation resistance and the passage resistance of the human body. The electric shock was not limited by F1 or S2 safety devices, because in both cases they are for delayed overload protection, with rated currents of 20A and 16A.

Another case of the electric shock on the *JAS 57* cutter has the same scenario, except that the victim was standing on a dry, rubber-covered deck. The electric current flew from the palm of the hand (the victim was also holding a plug of the extension cord in his hand) to his shoulder. The victim touched with his shoulder a steel frame of the door leading from the cutter's engine room to the deck as he was leaving the engine room.

The course of events during the first accident confirms the fact that the resistance of insulation of cutter's devices fed by 230V installation had been reduced. The witnesses of the incident confirmed that the RCCB device had been activated many times at the wharf of the fishing port in Władysławowo, when the cutter's power supply was connected to the electric network. Activation of such type of protection indicates that the insulation of the cutter's electrical system was damaged.

5.2. Causes of the Accident

Following the investigation,, the Commission concluded that the cause of the fatal accident of the motorman of the *JAS 57 Magdalena* cutter on 29 May 2019 during a stop at the port of Władysławowo was an electric shock resulting from a combination of four elements:

- improperly made electrical installation;
- lack of the as-built documentation of the changed electrical installation and operating instructions for the converter for the crew;
- unacceptable damage to the electrical installation resulting in the reduction of the insulation resistance of electrical devices supplied from 230V, 50Hz circuits;
- attempts to connect power from the shore directly through the converter not being aware of existing hazards related to the electrical installation in place.

In addition, the accident was caused by:

- insufficient supervision of the classification society over the reconstruction of the vessel in the part regarding changes made to the electrical installation, in particular setting up new devices without approval, lack of as-built documentation and instructions for the crew;
- limited scope of training of the engine crew of the fishing vessels in the field of electrical engineering and maritime electronics, especially when the motorman is the only member of the engine crew and operates all electrical appliances on board;
- late hour and fatigue of the entire crew or malaise in case of one of the victims.

5.3. Other Conclusions

The Commission additionally recognized that when the technical preparation of the engine crew for the safe operation of electrical equipment was limited, special responsibility for the safety of the vessel and the crew lies with the classification society and electrical service contractors, in particular those having specific qualifications granted by the classifier.

During an additional visit of the investigative team on board a cutter on 6 February 2020, it was found that a new converter had been installed, the installation had been repaired and an additional device to measure the state of insulation of the cutter's electrical installation had been installed.

Photograph 6: New devices installed on the JAS 57 cutter

Recognizing the steps taken by the operator under the supervision of the classifier and the National Labour Inspectorate, the Commission withdrew from issuing recommendations in that respect.

6. Safety Recommendations

The State Marine Accident Investigation Commission found it reasonable to address safety recommendations constituting proposals of actions that may contribute to preventing a similar accident in the future to the classifier of the vessel:

6.1. Classification Society – Polish Register of Shipping S.A. seated in Gdańsk

The Commission has recommended:

- to familiarize the employees with this report;
- to analyze and possibly change the regulations regarding electrical installations on small seagoing vessels, taking into account limited staffing as well as knowledge and experience of the crew on small vessels;
- to assess the principles of issuing PRS authorization to companies and monitoring the work performed;
- to additionally verify the existing electrical installation on small seagoing vessels for compliance with PRS requirements as part of the existing survey system.

7. List of Photographs

8. List of Figures

9. Information Sources

Materials and documents submitted by the operator, the Maritime Office in Gdynia, and the Polish Register of Shipping S.A.

Depositions of the operator and crew members

Photographs submitted by the cutter’s operator

Expert opinions made by Mr. Tomasz Gellert – the SMAIC expert

10. Notification of the Accident

The State Marine Accident Investigation Commission was notified about the casualty by electronic mail by MRCK [Maritime Search and Rescue Service] on 29.05.2019 at 07:58 and by the officer of the Władysławowo harbour master's office on 29.05.2019 at 14:09.

11. Composition of the Investigative Team

The team leader – Tadeusz Wojtasik, the Chairman of SMAIC

The team member – Marek Szymankiewicz, the Secretary

12. Annexes

12.1. Annex 1: Description of the Electric Installation of the Fishing Cutter

Main electrical installation of the *JAS 57* cutter is based on a 24VDC installation. The basic source of electricity on the vessel is an accumulator battery working with a shaft generator. During the operation of the main engine of the cutter, the shaft generator with an output voltage of 24VDC is used. This generator is one of the basic sources of electric power. It supplies the low-voltage loads necessary for navigation, fishing, safety systems and cutter communication. It works with the accumulator battery. The distribution of 24VDC electricity is carried out through the switchboard located in the wheelhouse of the vessel.

Photograph 7: 24 VDC power supply distribution panel

The operator switches on the 24VDC output circuits such as:

- Navigation lights,
- Radar,
- Autopilot,
- External lighting,
- AIS, GPS and other navigation devices.

If the main engine stops, electricity is obtained from 24VDC lead-acid accumulator batteries with a capacity of 170Ah each. Each 24VDC battery consists of two 12VDC accumulators with 170Ah capacity connected in series.

Photograph 8: Accumulator batteries

The accumulator batteries are charged while the main engine of the cutter is working thanks to the electricity generated by the 24VDC generator.

These batteries serve as starting batteries for the main engine of the vessel and supply for a certain time the electrical circuits necessary for safe operation of the cutter in various operating conditions.

The said 24VDC supply voltage is considered safe in accordance with PRS[5] requirements.

"Safe voltage - voltage that does not create the possibility of electric shock or burn under normal conditions. Such conditions are considered to be met if the windings of transformers, converters and other voltage-reducing devices are electrically separated and the reduced voltage of these devices or sources of electricity does not exceed: - at direct current - 50 V between the wires; - at alternating current - 50 V between the wires or between the hull and the phase."

In the circuits of the 24VDC system associated with two batteries of the lead-acid accumulators there is also a switch used to select the accumulator batteries which will start the main engine.

The engine can be started by means of the first or second starting battery. This element is shown in the figure below.

[5] Regulations for Classification and Construction of Small Sea-going Vessels, Part VII Electrical Installations and Steering Systems, PRS January 2016, hereinafter called PRS IESS Regulations.

Photograph 9: Starting battery selection switch

The auxiliary electrical installation installed on the *JAS 57* cutter is the alternating current installation. It includes a shore power socket with cabling. It makes it possible to connect by means of an external, portable cable, three-phase 3x400V 50Hz power supply from the wharf to the said shore power socket. This socket is installed on the front part of the superstructure.

Photograph 10: Socket for power supply from the shore

Thanks to such a solution, the crew of the cutter, after mooring in the port, can turn off the main engine of the vessel's propulsion. The shaft generator is then stopped. Electrical receivers can only be powered by electricity stored in the batteries for a specified period of time. The crew connects power supply from the shore through the socket shown in the Photograph 9 to ensure the continuity of power supply to the electric receivers of the cutter.

The shore power cable is connected to the power terminal installed on the wharfs of the fishing ports

Figure 6: Power terminal, the port of Władysławowo

The distribution of the 3x400V, 50Hz alternating voltage supply takes place through a switchboard installed in the cutter's control room. In the analyzed period, the shore supply of the cutter was carried out by means of a rubber insulated four-wire cable. The cable was connected to a 32A socket of the power terminal installed on the shore. On the day of the accident, during a stop at the Duńskie wharf of the Władysławowo port, the protection of this three-phase circuit consisted of:

- F13 residual current circuit breaker: Xpole PFIM 40/4/003, Moeller, which switches on at the current of 30mA,
- F3 circuit breaker: Xclear CL S6 - C32 / 3.

The 3x400V, 50Hz power socket protection circuits are shown in Figure 7.

Figure 7: Protection of the 32A socket circuit supplying power to the cutter on the day of the accident

12.2. Annex No 2 Electric Shock of the Skipper of JAS 57 on 11 July 2019

On July 11, 2019, the JAS 57 cutter was travelling between the ports of Jastarnia - Hel and Hel - Jastarnia, taking groups of tourists on board. After finishing the last crossing from Hel and mooring the cutter in the port of Jastarnia around 19:30, the skipper intended to connect the cutter's power supply to the power terminal available at the wharf.

There are three-phase (3x400V, 50Hz) 32 A sockets available at the wharf, with a neutral and protective wire and single-phase 230V, 50Hz sockets. That day, the crew of the vessel did not plan to connect the power system of the cutter to the onshore power network (3x400V, 50Hz) using the three-phase socket mounted for that purpose on the front part of the superstructure and a suitable three-phase power cable. The connection was attempted by means of a portable, household, single-phase cable, coiled extension cord (a 3-core 2x1mm2 cable ended with a plug on one side and a set of 4 sockets on the other and protected by the overload protection). It was intended to power the vessel's converter with this makeshift, temporary connection.

It was intended to supply electricity to the POWER SINUS 3000 24V high power converter, which was mounted in the cutter's engine room, from the 230V, 50Hz voltage source available at a short distance from the cutter mooring at the wharf of the port of Jastarnia.

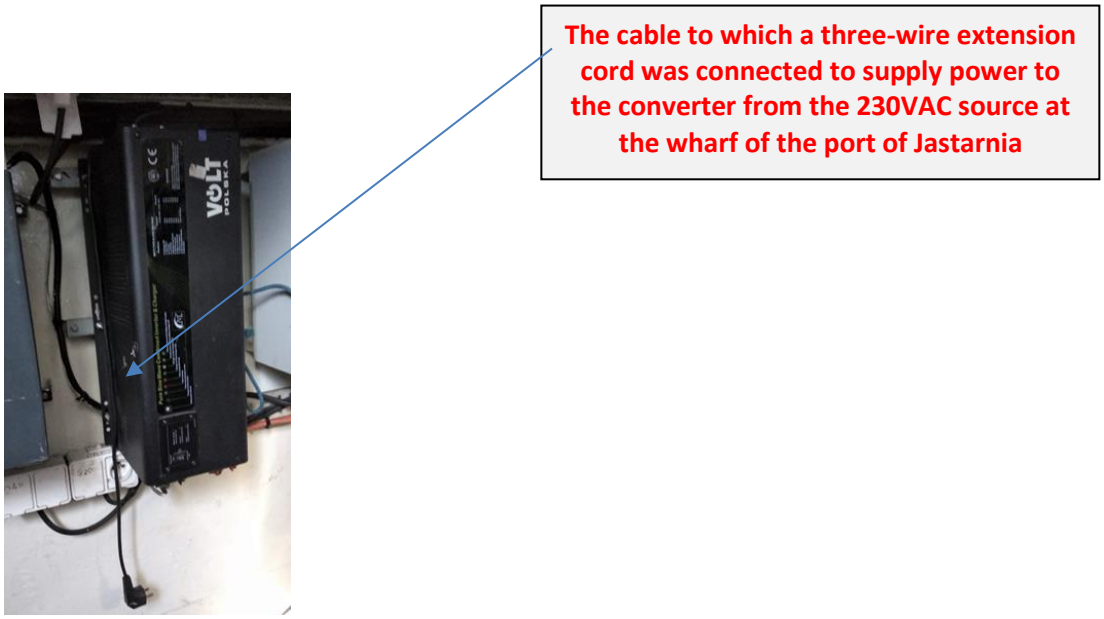


Figure 8: Power Sinus 3000 24V converter

After connecting the power supply cable of the 230VAC converter, marked with an arrow in Figure 8, by plugging it into the socket of the extension cord, the skipper left the cutter's engine room and went to the deck holding in his right hand the coil of cable with the intention of leaving the cutter and plugging the said cable into the 230VAC power supply at the wharf. At that moment he received an electric shock.

This accident occurred on the starboard side of the vessel, at the exit from the engine room. The place of this incident was identical to the place of a previous electrocution of the motorman. On the day of the accident the weather was sunny, there was no rainfall. At the time of the electric shock, the skipper was standing on a dry deck covered with a layer of rough, non-slip rubber. He was wearing soft plastic footwear - beach flip-flops and he was holding coiled cable in his hand. The man managed to toss the cable aside onto the deck, getting rid of the source of shock. At the time of the electric shock, the injured suffered pain and muscle cramps in his right arm. He did not feel the flow of electricity through other parts of the body. At the time of the event the entire arm was indisposed. Muscle pain and cramps were felt until late in the evening.

12.3. Annex 3: High Power Converter - Power Sinus 3000 24V

The operation of a cutter requires a basic source of electric energy of 24VDC. To meet this condition, the vessel has been equipped with a converter when supplied with electric 3x400V, 50Hz three-phase power from the shore. This device can function in the following was:

- as a 24VDC power supply and battery rectifier for charging the accumulator battery, the primary source of electric energy. This condition occurs when the converter is powered from an external 230VAC power source, e.g. while at a stop in the port. Conversion of 230VAC to 24VDC.
- A converter converting 24VDC direct voltage (taken from basic sources of electricity, e.g. batteries) into 230VAC, 50Hz alternating voltage. Conversion of 24VDC to 230VAC. Such situation occurs when no shore power supply is connected. This is the inverter mode of work.

The crew of the *JAS 57* cutter connected the power to the inverter in two ways:

- 3x400VAC shore power was connected to the socket mounted on the front side of the superstructure. Then, electricity from the three-phase socket was supplied through overcurrent protection, located in the wheelhouse panel, to the 230VAC sockets located in the engine room of the cutter. The converter was connected to such a 230VAC socket.

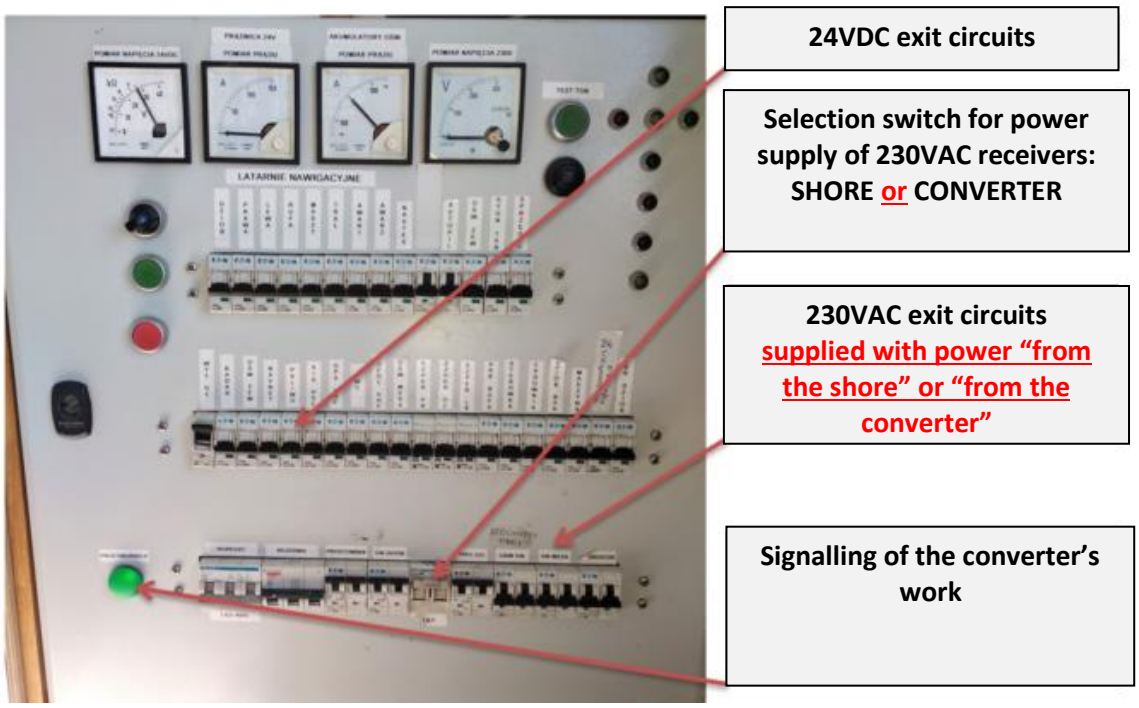


Figure 9: Switchboard at the bridge

- Another way in which the crew connected the power for converter in the port was to feet it directly from the wharf from a 230VAC socket using a portable extension cord. Then no external three-phase shore power socket was used.

The power was supplied to the converter by means of the second method in both cases of electric shock on the *JAS 57* cutter.

In the period until 15 July 2019, a high power emergency power supply Sinus 3000 24V[6] was installed on the cutter, hereinafter referred to as the converter. The provisions of the act on Marine Equipment do not apply to converters used on vessels. Recognition of the product and, at the same time, the possibility of installing such a device on the ship's side are determined by the classifier.[7]

*"**1.3.3.2** 12 V and 24 V devices for, which are not manufactured under PRS supervision, may be used after prior agreement with PRS."*

On page 4 of the user's manual there is a general description of the device – "*The emergency power supply device of the POWER SNUS series are a combination of a converter, a universal rectifier and an automatic NETWORK switch (AC) in one system with a peak DC/AC conversion efficiency of approx. 88%.*"

A section containing general safety information (page 3 of the user's manual) contains key information – "*This device contains components that may cause sparkling. To avoid fire and/or explosion, do not install the device in rooms containing batteries or flammable materials, or in a place containing devices that cannot be in contact with fire. This includes all locations where gasoline-powered machinery, fuel tanks, fittings, binders, or other connections between fuel system components are stored*." The applications for this type of converter are given on page 5 of the manual:

- *„High power devices including: circular saws, drills, grinders, milling machines,* sandblasters, *grass and hedge care devices, air compressors, etc.;*

- *office equipment, among others: computers, printers, monitors, fax machines, scanners, shredders. etc.;*

[6] User's manual and the data sheet are available on the website : www.voltpolska.pl.
[7] Clause 1.3.3 of the PRS IESS Regulations.

- *home appliances including: vacuum cleaners, windmills, lighting, shavers, sewing machines, etc.;*

- *kitchen appliances, among others: coffee machines, blenders, toasters, refrigerators, microwaves, etc.;*

- *industrial equipment, among others: halogen and sodium lamps, compressors, motors, pumps, etc.;*

- *home entertainment devices, e.g. TV sets, home cinemas, consoles, audio devices, sat boxes, etc."*

Examination of the Power Sinus 3000 24V converter.

High Power Emergency Power Supply Power Sinus, distributed by Volt Polska Sp. z o. o. and hereinafter referred to as the **Power Sinus 3000 24V converter** or the **converter** is shown in Photograph 10.

The data plate of the converter and its serial number are shown in Photograph 11.

Serial number of the above device: 1121630240020.

Photograph 11: Power Sinus 3000 24V converter

Photograph 12: Data plate of the converter

Full data of the Power Sinus 3000 24V converter and its comprehensive description of operation are included in the documents available on the website of the converter's distributor – the company Volt Polska Sp. z o. o: www.voltpolska.pl

Reasons for examining Power Sinus 3000 24V converter.

The investigation aimed at clarification of the causes and circumstances of the accidents that occurred on the fishing cutter, *JAS 57 Magdalena* in fishing ports of Władysławowo and Jastarnia on 29 May and 11 July 2019.

In both cases, the crew members of the *JAS 57* cutter suffered an electric shock. The injured persons carried out activities with the intention to connect the 230V single-phase power supply to the Power Sinus 3000 24V converter. The crew members intended to power the converter connected by a portable power cable (extension cord) from a 230V, 50Hz electric socket on the wharf. Holding a portable cable in their hand, one end of which (extension socket) was connected to the converter, they had access to the exposed parts of the plug (on the other end of the extension cord).

While leaving the cutter's engine room to the main deck, the victims received an electric shock.

The question arises of how an electric shock could occur if the victims were in the course of activities aimed at connecting the converter's power supply. The portable cable was connected only to the power supply connections of this device.

The way the crew of the *JAS 57* cutter connected the converter is shown in Figure 10.

This is the way the crew of the *JAS 57* cutter connected 230VAC source to the Power Sinus converter. The cable lead though the waterproof door leading to the engine room of the vessel.

Figure 10: Connection of the converter to the shore power supply

Investigation of the Power Sinus 3000 24V converter

The investigation was aimed at answering the following question:

Due to the circumstances of the accidents that had occurred on the *JAS 57* cutter could have dangerous voltage appeared there on the tested device, its housing or electrical power terminals leading to an electric shock given to a member of the crew of the *JAS 57* cutter?

In order to properly examine the converter, electrical connections similar to those used on the *JAS 57* cutter were made. The following elements were used in the examination:

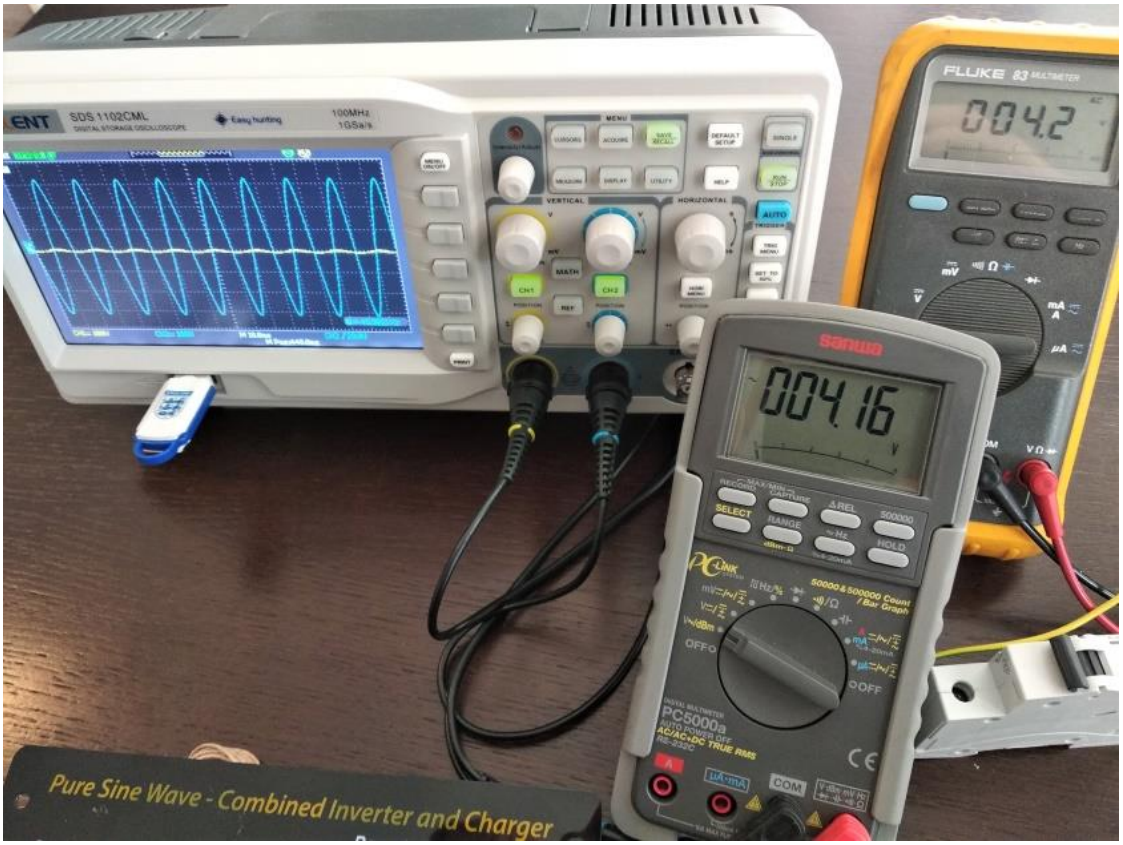
- Power Sinus 3000 24V converter,
- TUBORG lead-acid batteries, TS575 - 075, 12V, 75Ah, 750A, 2 pieces,
- LCD panel for the Power Sinus power supply.

The LCD panel shown in Photograph 10 makes it possible to control the converter remotely and to see its basic operating parameters. The LCD panel was mounted in the cutter's superstructure, which made it possible to switch the converter and to select the operating mode selected regardless of the position of the switch installed on the converter.

For correct analysis of the voltage wave forms on the converter's terminals, the following devices were used:

- Digital oscilloscope, Siglent SDS 1102 CML, 100MHz, 1GSa/s,
- Digital meter, FLUKE 83,
- Digital meter, Sanwa 5000a,

The measuring apparatus is shown in Photograph 12.



Photograph 13: Measuring circuit

The electric schematic diagram for the analysis of the converter's work is presented on Photograph 11.

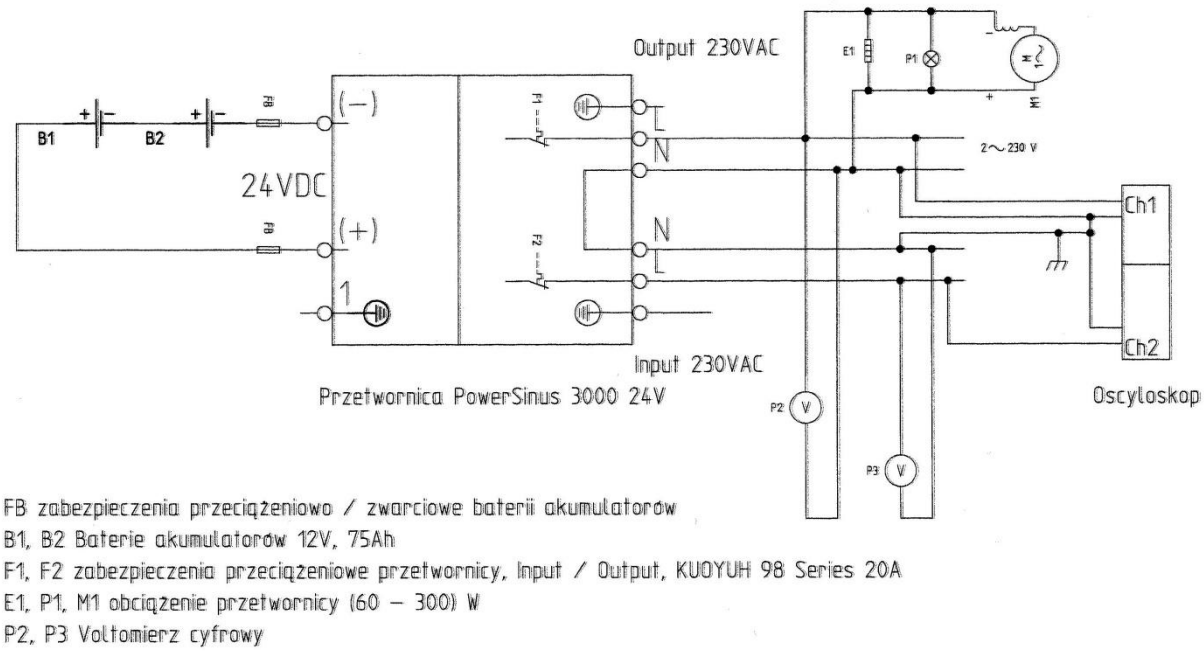


Figure 11: Schematic diagram for the analysis of the converter's work

The Power Sinus converter is a combination of a converter that converts electricity accumulated in B1 and B2 batteries to 230V, 50Hz alternating voltage and a battery charger. Alternating voltage generated by the device is available on its output terminals (Output 230VAC). This device also performs the function of a battery charger when power is available from the external 230V, 50Hz circuit (connected to the Input 230VAC terminals). In such operating mode, the converter can charge the batteries and simultaneously supply electricity to devices connected to the converter's output terminal (Output 230VAC).

In order to analyze the possibility of appearing some dangerous electrical voltage at the input terminals of the converter (Input 230VAC), the batteries were connected to the device according to the schematic diagram. An electrical load was also connected to the output terminals, Output 230VAC. Using the available LCD panel as well as using the converter's mode switch, all possible operation modes of the converter were used.

Voltage waveforms at the input and output of the converter were recorded in various operation modes and control states by means of a two-channel oscilloscope. Indications of digital voltmeters were also observed.

Voltage change waveforms recorded by means of the two-channel oscilloscope with particular regard to the input terminals (Input 230VAC) are presented below.

The accumulator batteries used for the tests are shown in Photograph 13.

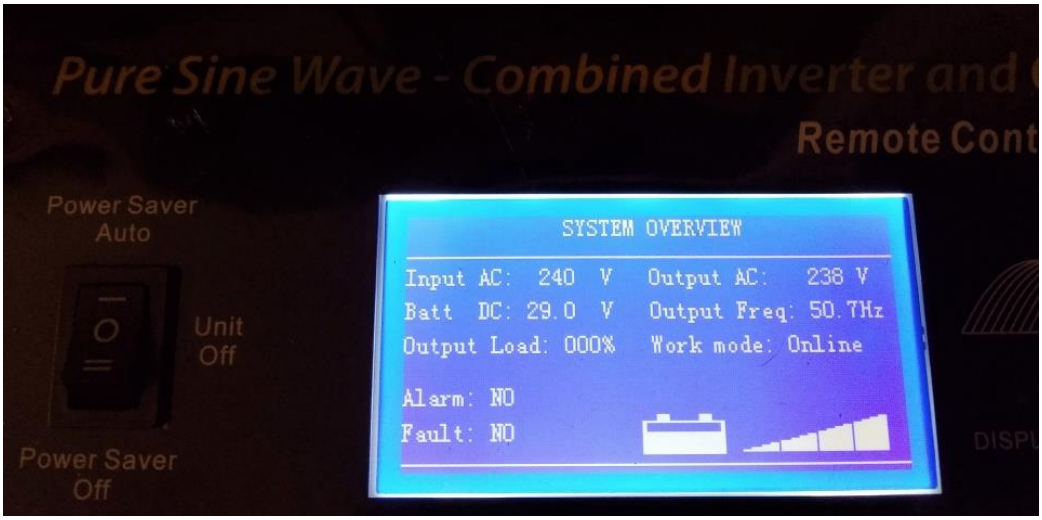
Photograph 14: Accumulator batteries for tests

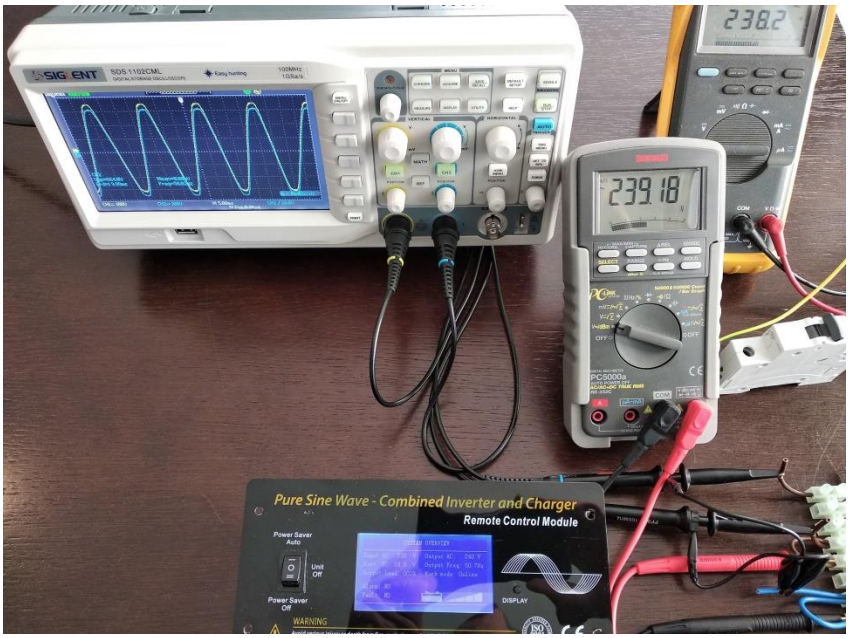
The results of testing the waveforms and voltage values appearing at the input terminals of the Power Sinus 3000 24V converter in various operation modes.

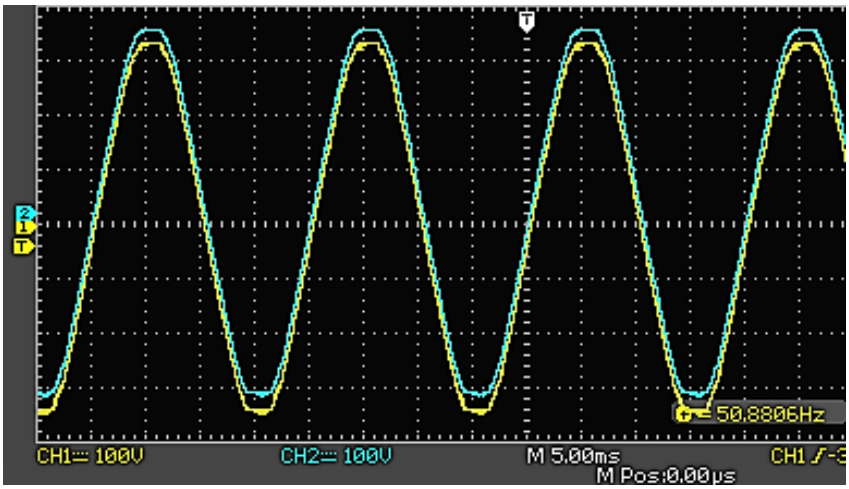
The converter has three modes of operation:

- „0" – the converter is switched off,
- „Power Saver Auto"
- „Power Saver Off".

- Operation mode: Power Saver Auto, U input = 230VAC, U output = 230V, 50Hz





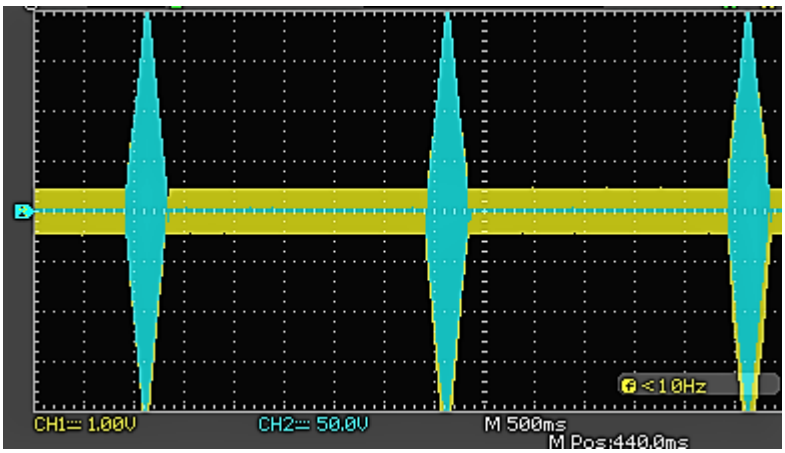


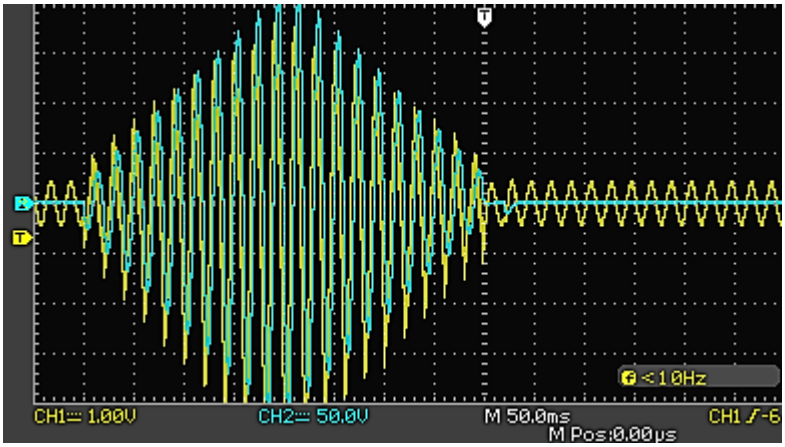
Photograph 15: Results of the Power Saver Auto operation mode, U input = 230VAC, U output = 230V, 50Hz

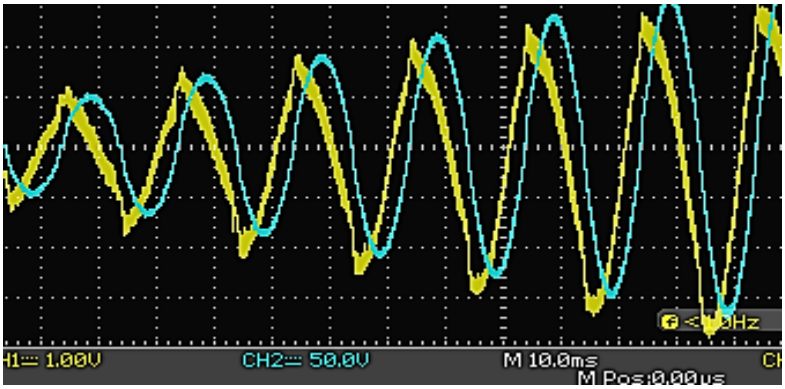
➢ <u>Operation mode: Power Saver Auto, U input = 0VAC, U output = Variable</u>

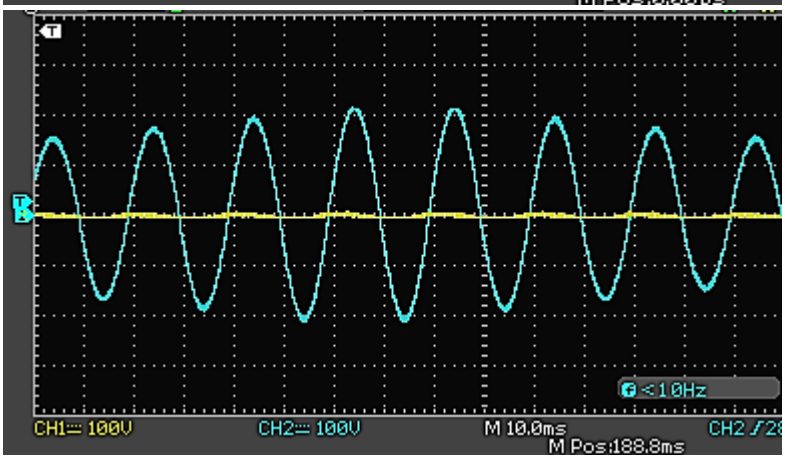
Converter mode; the converter has no input power, it consumes energy from accumulator batteries. The output voltage is variable; the converter is waiting for appropriate load to be connected to the output terminals. Output voltage pulses test the load, when it is lower than assumed, the converter does not generate full 230V, 50Hz at its output - it saves energy.

- Yellow waveforms indicate the converter's input voltage, U Input.
- Blue waveforms indicate converter's output voltages, U Output.
- Digital voltmeters measure input voltage.









Photograph 16: Results of the Power Saver Auto operation mode,
U input = 0VAC, U output = Variable

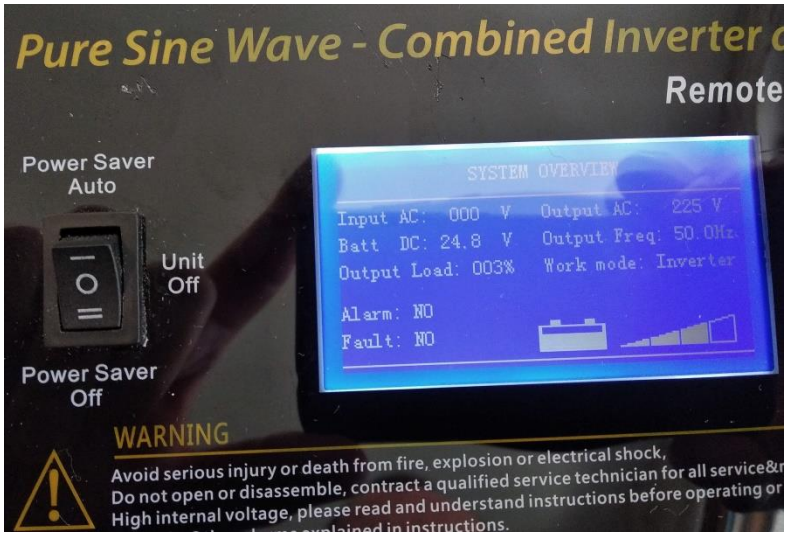
Repeated attempts to force transient states involving switching the converter on and off and connecting variable loads, in the Power Saver Auto operation mode did not cause any voltage signals at the converter's input that could cause electric shock. Maximum input voltage amplitudes do not exceed 5V, the duration of these signals is about 400ms.

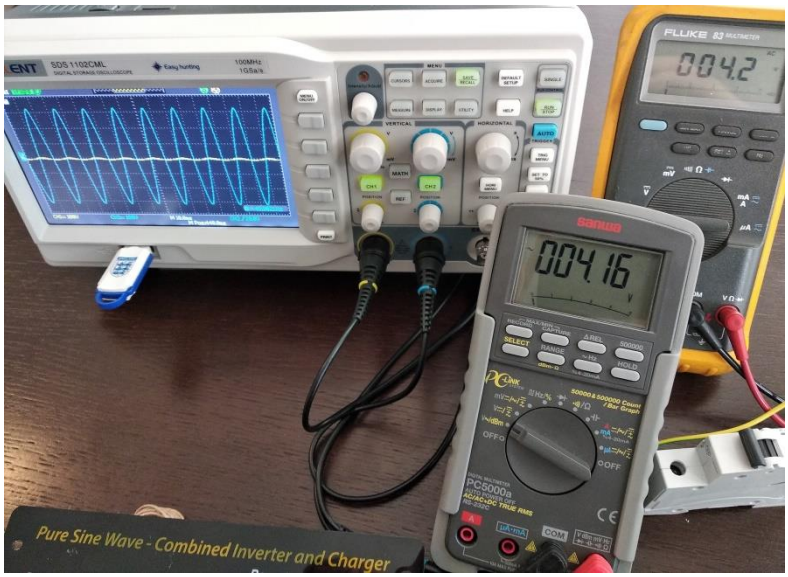
Conclusion: no voltage on the input terminals of the converter in the Power Saver Auto operation mode was found that could have caused electric shock.

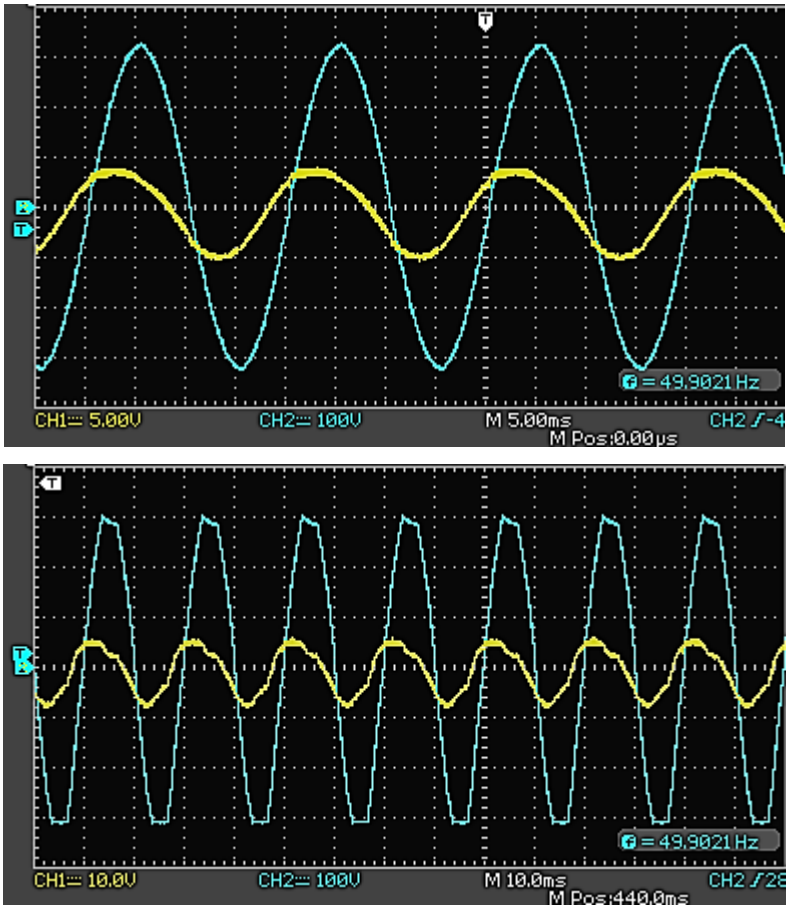
➢ <u>Operation mode: Power Saver Off, U input = 0VAC, U output = 230V, 50Hz</u>

Inverter operation mode; the converter has no input power, it consumes energy from a battery accumulator. It produces full 230V, 50Hz output voltage.

- Yellow waveforms indicate the inverter input voltage, U Input.
- Blue waveforms indicate inverter output voltages, U Output.
- Digital voltmeters measure the input voltage.







Photograph 17: Results of the Power Saver Off operation mode,
U input = 0VAC, U output = 230V, 50Hz

Repeated attempts to force transient states involving switching the converter on and off and connecting variable loads, in the Power Saver Off operation mode did not cause any voltage signals at the converter's input that could cause electric shock. Maximum input voltage amplitudes do not exceed 8V. This occurs in states when a loaded converter generates distorted output voltage. When the load is minimal, the observed input voltage have effective values indicated by both digital multimeters at ca 4V. These values are confirmed by waveforms recorded on the oscilloscope.

Conclusion: the Power Saver Off converter was not found in its operating mode at its input terminals for voltages that may cause electric shock.

Conclusion: no voltage on the input terminals of the converter in the Power Saver Off operation mode was found that could have caused electric shock.

During the examination of the converter, its insulation resistance was also checked. Measurements of insulation resistance of all L terminals, N input and output circuits in relation to the protective terminal showed values of about 3GOhm, when measuring 500VDC, at an ambient temperature of 20ºC and relative humidity of 60%.

To sum up, during the test it was not possible to cause a state in which the converter would generate voltages that could cause electric shock on its input/power terminals (230V) and housing.