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Smart Synchronizer SS-07

Specification „-3D"

Operating Manual

(ver. 1.05)

CE

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MEANING OF OPERATING MANUAL

If you have any doubts about this manual please ask manufacturer for more detail information.

We will be grateful for every suggestions, opinions or critical remarks given us by users so please, communicate them to us in written or oral form. It will help us to make this instruction more helpful and easy to use and take into account user requests and demands.

Device this manual is delivered with, can cause potential, impossible to eliminate, risk for person or property. Therefore every person working with our device or performing any service or maintaining activities concerning this device should be previously properly trained and know possible threats. This can be achieved by reading this manual carefully, understanding it and obeying it's recommendations, especially safety instructions.

Contents

DECLARATION OF CONFORMITY

The device being a subject of this manual is intended for applications in industrial environment. At design and manufacturing stages of this device such standards were applied, complying with which guarantees realization of established principles and safety measures, under the condition of following by the user given below guidelines for installation, start-up and operation.

This is a Class A device. In residential environment it can cause electromagnetic interferences. In such cases one can require of device user to apply proper preventive measures.

This device is in conformity with provisions of following EC directives:

2006/95/WE LVD - Directive 2006/95/EC of the European Parliament and of the Council of 12 December 2006 on the harmonisation of the laws of Member States relating to electrical equipment designed for use within certain voltage limits - introduced on Polish Republic territory by order of Minster of Economy of 21 August 2007 on fundamental requirements for electric equipment (Journal of Laws No. 155, pos. 1089).

2004/108/WE EMC - Directive of the European Parliament and of the Council of 15 December 2004 on the approximation of the laws of the Member States relating to electromagnetic compatibility – introduced on Polish Republic territory by Law of 13 April 2007 on electromagnetic compatibility (Journal of Laws No. 82, pos. 556).

Conformity with Directives was confirmed by tests preformed by independent from manufacturer measurement and research laboratories.

Device fulfils main requirements determined in Directives: Low Voltage (**2006/95/WE**) and Electromagnetic Compatibility (**2004/108/WE**), by conformity to standards:

Standard harmonized with Directive LVD 2006/95/EC

- **PN-EN 60255-27:2006 -** Power relays – Part 5: Insulation coordination of measurement relays for protective devices. Requirements and tests. Measurement relays and protective devices -- Part 27: Product safety requirements

Standard for Directive EMC 2004/108/EC

- **PN-EN 60255:2010 -** Measurement relays and protective devices – Part 26: Requirements concerning electromagnetic compatibility.

1. Application of the device

Microprocessor Network Synchronizer SS-07-3D is an enhanced version of the synchronizer SS-07 and is intended for automatic connection of electric AC power systems for parallel operation. Synchronizer can operate in several modes selected automatically in dependence on the state of monitored switching devices in the substation, voltage levels, defined settings and configurations and chosen setting banks.

Synchronizer SS-07-3D can perform automatic selection of following operation modes:

- automatic synchronisation with constant time advance,
- connecting separated electric power systems,
- turning on the breaker without voltage at one or both sides.

Particular emphasis in design of SS-07-3D synchronizer was put on reliability and switching accuracy. Unique method of realization of constant time advance was applied in this devices, based on advanced signal processing technique, guaranteeing switching at deviations less than 2 degrees.

Unique features of SS-07-3D synchronizer are:

- possibility of connecting all measuring, test and control circuits to the synchronizer without switching to enable maximization of reliability and availability of synchronization system,
- identification of current operational arrangement of switching station,
- simultaneous performing of high precision measurements in four control points of power system (e.g. for one arm in 1.5 circuit-breaker switching station – measurements in two systems and two feeders),
- simultaneous determination of synchronization criteria parameters for all possible directions of connection of selected switch bay to the power system,
- presentation of fulfilled synchronization criteria conditions before starting the switching process,
- independent control of up to three circuit breakers,
- frequency equalization taking into account dynamic parameters of drive system, enabling turning on within several dozens of seconds (in generating systems),
- voltage equalization taking into account dynamic parameters of voltage control system (in generating systems),
- fast communication lines (Fast Ethernet) for cooperation with master control and monitoring systems,
- synchronizer front plate provided with LCD display, keyboard and signalling lamps particularly useful during start-up of automatic synchronization process in facility or during routine check of synchronization process run,
- possibility of direct connection of synchronizer (via optical fibre or twisted pair) with second graphical HMI terminal working as synchronization table (TS-20), intended for installation on control desk in control room, back-up panels or instead of front panel directly on SS-07-3D synchronizer.

1.1. Switching in voltage modes

Voltage modes are used for switching of power systems in situations, when both sides of closed circuit breaker are live.

1.1.1. Automatic synchronisation with constant time advance (SYN)

SYN mode is used for switching of power systems operating asynchronously. In this mode synchronizer can, if it is possible, send control pulses decreasing in this way permissible voltage and frequency differences to levels set by the user.

In station solution, when synchronizer has no influence on the state of switched power systems and adjustment is not possible, set permissible conditions for voltage and frequency differences should be fulfilled already at the moment of sending "Start" signal starting the switching process.

1.1.2. Switching in pre-set angular sector (ZSK)

ZSK mode is used for switching power systems when synchronizer has no influence on voltages and frequencies in switched systems and it has to connect them when switching conditions determined in settings are fulfilled. After receiving "Start" signal synchronizer generates closing pulse only when voltage difference, phase difference and phase drift in the set limiting time interval does not exceed corresponding set permissible values.

1.2. Switching in none-voltage modes

Potential-free modes are used for switching of power systems in situations, when almost one side of closed circuit breaker is in dead state.

1.2.1. SBN switching

SBN mode is used for closing circuit breaker when both rms voltage value and frequency of reference bay include in required range and voltage of self-bay is included in residual range. Residual voltage check is aimed at detection of situations when busbars of self-bay are shorted.

1.2.2. GBN switching

GBN mode is used for closing circuit breaker when rms voltage value and frequency of self-bay voltage are included in required range and voltage of reference bay is included in residual range. Residual voltage check is aimed at detection of situations when busbars of reference bay are shorted

1.2.3. SGBN switching

SGBN mode is used for circuit breaker closing controlled by the synchronizer when both sides of the breaker are dead. Residual voltage is checked at both sides of circuit breaker. Residual voltage check is aimed at detection of situations when any busbar system is shorted.

1.3. Connection without synchronism control

BKS mode - under certain circumstances it might be necessary to close circuit breaker in the system without synchronism control. This may happen when as a result of a certain position of disconnectors and/or other circuit breakers, the closing of circuit breakers will not lead to the connection of two, previously separate, voltage systems.

2. Safety instructions

Informations contained in this chapter are intended to familiarize user with proper installation and operation of the product. It is assumed that personnel installing, commissioning and operating this device possess proper qualifications and is conscious of potential risks connected with work with electric equipment.

Device fulfils requirements of binding regulations and standards in the scope of safety. Special attention was paid in its design to safety of users.

Installation of the device

Device should be installed in place providing proper environmental conditions, as determined in specifications. Device should be properly fitted, protected against mechanical damages and accidental access of non-authorized persons. Synchronizer is adapted to under board mounting in indoor switchgear. Synchronizer should be connected in accordance with electrical diagram. External connections are lead via separable spring joints from WAGO Company. It is recommended to perform connections of synchronizer using conductors of LY type and cross-section of 1.0÷2.5 mm^2.

Synchronizer SS-07-3D is manufactured in I Class of protection and requires connecting of protective conductor of installation to properly marked terminal on the housing.

Commissioning of the device

After synchronizer is installed it should be commissioned according to widely accepted principles concerning protective devices, automation and control.

Insulation test can cause charging of dispersed capacitances up to dangerous voltage. After completion of each part of test one should discharge these capacitances.

Operation of the device

Device should be operated in conditions determined in specifications.
Persons operating the device should be authorized and familiarized with operating manual.

Removing of the enclosure

Before starting any works associated with the need to remove casing one should stringently disconnect all powering and measuring voltages and then detach the synchronizer from external circuits taking all plugs out.

Used components are sensitive to electrostatic discharges therefore opening of the device without proper antistatic equipment can cause its damage.

Maintenance

After installation device need not any additional service apart from periodic inspections requires by adequate regulations. In case of detecting a defect one should turn to the manufacturer.

Manufacturer provides guarantee service and post-warranty after sales service. Terms of the guarantee are defined in a warranty card.

Modifications and changes

Due to safety any modifications and changes of features of the device this manual concerns are prohibited. Modifications of the device, to which manufacturer didn't give the written consent cause loss of all claims on account of the responsibility against PUP Kared Spółka z o.o.

Exchange of elements and components being included in a device for those coming from other producers than applied, can disturb safety of users and cause malfunction of the device.

PUP KARED Sp. z o.o. Company isn't liable for damages caused by applying improper elements and components.

Disturbances

When any disturbances in operation of the device or other faults are observed, a competent person should be informed immediately.

Repairs can be performed exclusively by skilled specialists.

Rating plates, information plates and labels

One should strictly observe guidelines given in the form of descriptions on the device, information plates and labels and keep them in the state ensuring their good legibility. Plates and labels which were damaged or became illegible, should be exchanged.

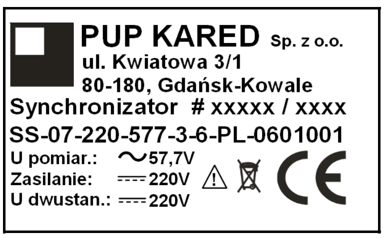

Fig 2.1. Design of rating plate

Risks impossible to eliminate

In conditions of normal operation one should not touch terminals of the device due to dangerous for persons voltages present on them.

3. Technical description and operation of the device

3.1. General description

Synchronizer SS-07-3D design is based on microprocessor technique. Components of the device are fitted in 19" Euro 3U cartridge in table mounted execution.

4 measured voltages, including one tri-phase and digital signals for locking, start and determination of states of circuit breakers and disconnectors are led to the synchronizer, which determines operating conditions on the base of those signals and automatically performs selected type of switching.

Synchronizer is designed for operation in network of 50 Hz frequency.

Typical applications of synchronizer SS-07-3D are presented in figures 3.1 i 3.2.

In the second case synchronizers are duplicating their measurements enabling verification of measuring components operation..

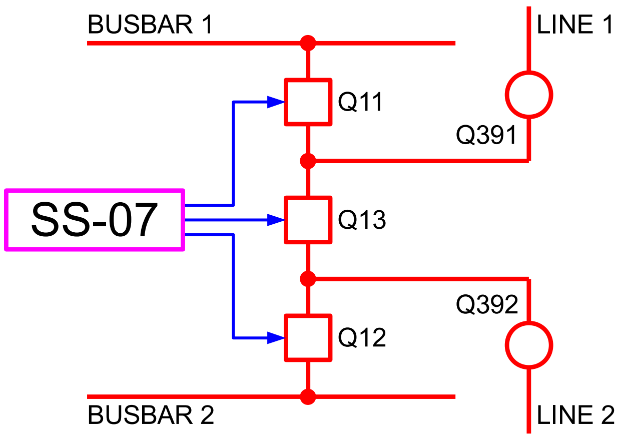

Fig. 3.1. Single synchronizer

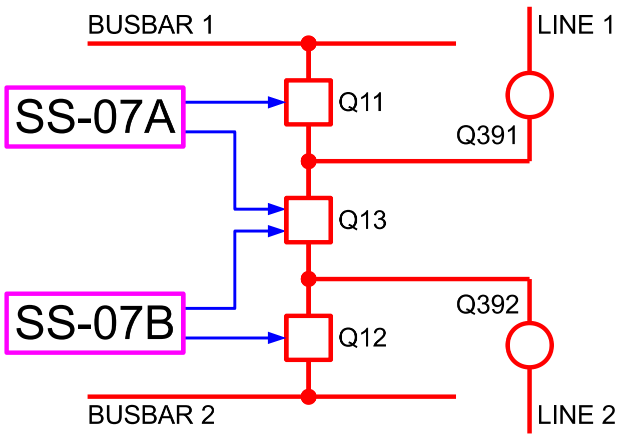

Fig. 3.2. typical application of two synchronizers in 1.5 circuit breaker switching station

3.2. Casing

SS-07-3D synchronizers are manufactured in casings for table mounting (cartridge Euro 19” 3U) of width 84T intended for fitting in typical cubicles adapted for installation of 19" cartridges.h.

Figure 3.3 presents a typical casing.

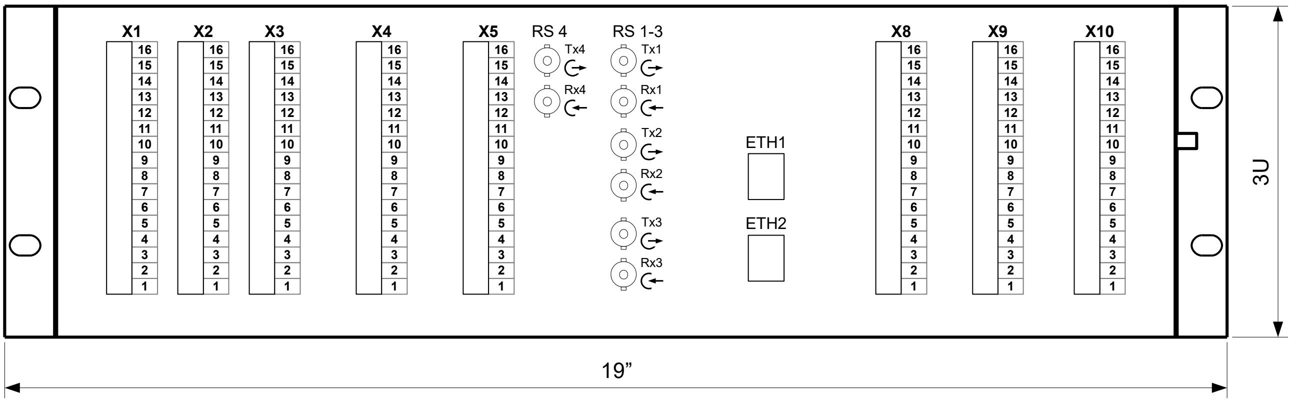

Fig. 3.3 Casing view (from the side of connectors)

3.3. Synoptic Table

Synchronizer SS-07-3D is provided with synoptic plate, placed in front panel of the device and facilitating especially first start of automatic synchronization process.

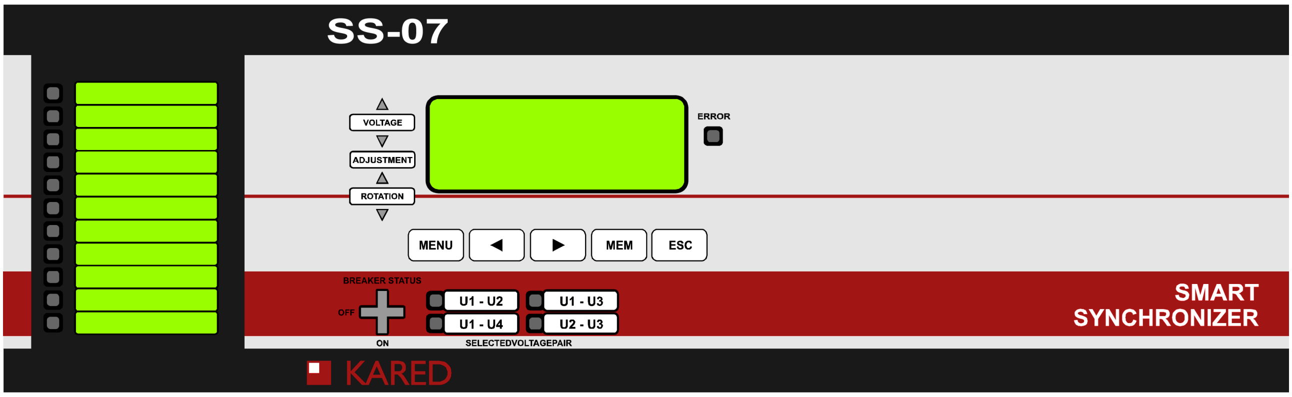

Fig. 3.4. Front plate view of synchronizer SS-07-3D

On the left side of the plate LEDs are located indicating operating mode of the device, possible switching directions and reliability of voltage measurements.. In central part of the plate there is LCD display, buttons (keyboard) and LEDs indicating selected voltage pair. LED for error signalization is located on the right from LCD.

In central part of synoptic plate, under the text CONTROL, at texts VOLTAGE and ROTATION arrows are placed, highlighted according to pulses generated by synchronizer, influencing voltage and angular speed controllers of turbine set. The arrows directed up are highlighted when signals increasing voltage and frequency are generated. Corresponding arrows directed down are highlighted when signals decreasing voltage and frequency are generated.

Actual status of the breaker is indicated by amps forming a cross. Horizontal bar of the cross highlighted green (OFF) means, that the breaker is opened, vertical bar highlighted red (ON) indicates that the breaker is closed.

State of selected circuit breaker is indicated only during synchronization process.

3.4. Signalling of errors

3.4.1. External errors

External errors are signalled on the display by text messages. This kind of errors includes failures and errors occurring outside of the synchronizer, connected with not proper configuration of input signals (for example caused by wire break, faulty contact etc.) or impossibility of synchronization performing.

3.4.2. Internal errors

Internal errors can occur in consequence of synchronizer's operating errors.. They are signalled on the display by numerical code. When internal error occurs, its code number should be noted, turn off synchronizer's power supply and turn on it again. If after this action the same error message appears again, manufacturer service should be called, because the synchronizer itself may be defected.

3.4.3. Error or blocking signalling using contact output (BL)

Internal errors can occur in consequence of synchronizer's operating errors.. They are signalled on the display by numeri

The BL relay is used to communicate via contacts about equipment error or blocking.

The BL signal may occur under the following circumstances:

- Successful synchronisation process (circuit breaker closing) – interim blocking, it is removed automatically once the registration is over.
- Failure of circuit breaker closing – interim blocking it is removed automatically once the registration is over.
- Internal fault has been detected – an additional signalling also appears at the UW output.
- Supply voltage loss (fading) below the required minimum (approx. 152 V)
- Information has been displayed about failure of any of the fuses of measuring transformers (U1-OK,...,U4-OK inputs).*
- Ambiguous status persisting for minimum Twyl (table 3.3 #28) seconds of any of the controlled circuit breakers (subject to matrix configuration). *
- The ambiguous status persisting for minimum Todl (table 3.3 #29) seconds of any of the controlled disconnectors (subject to matrix configuration). *

*) Synchronizer SS-07-3D takes into consideration only the status of the inputs that occur at least once in the status matrix (Section 3.5.4.)

3.5. Description of operation

This chapter contains detailed description of operation of synchronizer SS-07-3D from start-up the device, procedures in case of anomalies and realization of synchronization process.

3.5.1. Introduction – definitions and designations

Synchronizer power supply

1. **Uv** – The supply voltage with the rated value of 220 V DC.

Analogue input signals

1. **U1** – Three-phase measuring input, one-phase measuring input optionally (depends on setpoint U1-3f (table 3.3 #16),
2. **U2** – Three-phase measuring input, one-phase measuring input optionally (depends on setpoint U2-3f (table 3.3 #17),
3. **U3** – Three-phase measuring input, one-phase measuring input optionally (depends on setpoint U3-3f (table 3.3 #18),
4. **U4** – Three-phase measuring input, one-phase measuring input optionally (depends on setpoint U4-3f (table 3.3 #19).

Measuring voltage pairs

1. **U1-U2** – U1-U2 voltage pair, where Uw = U1, Uo = U2,
2. **U1-U3** – U1-U3 voltage pair, where Uw = U1, Uo = U3,
3. **U1-U4** – U1-U4 voltage pair, where Uw = U1, Uo = U4,
4. **U2-U1** – U2-U1 voltage pair, where Uw = U2, Uo = U1,
5. **U2-U3** – U2-U3 voltage pair, where Uw = U2, Uo = U3,
6. **U2-U4** – U2-U4 voltage pair, where Uw = U2, Uo = U4,
7. **U3-U4** – U3-U4 voltage pair, where Uw = U3, Uo = U4.

Voltages measured from the connection logic perspective

1. **Uw** – Own voltage; Uw is defined as the first voltage for a certain pair,
2. **Uo** – Reference voltage; Uw is defined as the first voltage for a certain pair.

Frequencies measured from the connection logic perspective

1. **fw** – Frequency of own voltage,
2. **fo** – Frequency of reference voltage.

Discrete input signals

A. Operation type selection signals:

1. **TEST** – Review and modification of set points and measurements of some facility parameters,
2. **SYN –** Operation mode SYN, if the setpoint Atrb = 0 (table 3.3 #20),
3. **ZSK –** Operation mode ZSK, if the setpoint Atrb = 0 (table 3.3 #20),
4. **SBN –** Operation mode SBN, if the setpoint Atrb = 0 (table 3.3 #20),
5. **GBN –** Operation mode GBN, if the setpoint Atrb = 0 (table 3.3 #20),
6. **SGBN –** Operation mode SGBN, if the setpoint Atrb = 0 (table 3.3 #20).

B. Control signals:

1. **START-1** – START of switching process by means of circuit breaker W1,
2. **START-2** – START of switching process by means of circuit breaker W2,
3. **START-3** – START of switching process by means of circuit breaker W3,
4. **BLKZ** – Blocking of the signal switching on the circuit breaker,
5. **WBR1** – Signal selecting either synchronizer's operation or giving permission for switching via circuit breaker W1, if the setpoint 3WBR = 1 (table 3.3 #26),
6. **WBR2** – Permission for switching via circuit breaker W2, if the setpoint 3WBR = 1 (table 3.3 #26),
7. **WBR3** – Permission for switching via circuit breaker W3, if the setpoint 3WBR = 1 (table 3.3 #26).

C. Sygnały stanu wyłącznika:

1. **W1o** – Circuit breaker /disconnector W1 opened,
2. **W1z** – Circuit breaker /disconnector W1 closed,
3. **W2o** – Circuit breaker /disconnector W2 opened or switching system control input, if the setpoint Kom = 1 (table 3.3 #30),
4. **W2z** – Circuit breaker /disconnector W2 closed or switching system control input, if the setpoint Kom = 1 (table 3.3 #30),

5. **W3o** – Circuit breaker /disconnector W3 opened or switching system control input, if the setpoint Kom = 1 (table 3.3 #30),
6. **W3z** – Circuit breaker /disconnector W3 closed or switching system control input, if the setpoint Kom = 1 (table 3.3 #30),
7. **W4o** – Circuit breaker /disconnector W4 opened or switching system control input, if the setpoint Kom = 1 (table 3.3 #30),
8. **W4z** – Circuit breaker /disconnector W4 closed or switching system control input, if the setpoint Kom = 1 (table 3.3 #30),
9. **W5o** – Circuit breaker /disconnector W5 opened or switching system control input, if the setpoint Kom = 1 (table 3.3 #30),
10. **W5z** – Circuit breaker /disconnector W5 closed or switching system control input, if the setpoint Kom = 1 (table 3.3 #30),
11. **W6o** – Circuit breaker /disconnector W6 opened or switching system control input, if the setpoint Kom = 1 (table 3.3 #30),
12. **W6z** – Circuit breaker /disconnector W6 closed or switching system control input, if the setpoint Kom = 1 (table 3.3 #30),
13. **W7o** – Circuit breaker /disconnector W7 opened or switching system control input, if the setpoint Kom = 1 (table 3.3 #30),
14. **W7z** – Circuit breaker /disconnector W7 closed or switching system control input, if the setpoint Kom = 1 (table 3.3 #30),
15. **W8o** – Circuit breaker /disconnector W8 opened or switching system control input, if the setpoint Kom = 1 (table 3.3 #30),
16. **W8z** – Circuit breaker /disconnector W8 closed or switching system control input, if the setpoint Kom = 1 (table 3.3 #30).

D. Generator setpoint selection signals:

1. **Gen1** – Generator 1 setpoints,
2. **Gen2** – Generator 2 setpoints.

E. Setpoint bank selection signals:

1. **Bank-1** – Setpoint Bank No. 1,
2. **Bank-2** – Setpoint Bank No. 2,
3. **Bank-3** – Setpoint Bank No. 3,
4. **Bank-4** – Setpoint Bank No. 4,

F. Measuring voltage reliability information signals

1. **U1-OK** – Voltage measuring transformer U1 – operational,
2. **U2-OK** – Voltage measuring transformer U2 – operational,
3. **U3-OK** – Voltage measuring transformer U3 – operational,
4. **U4-OK** – Voltage measuring transformer U4 – operational,

Discrete input signals (relay contacts)

A. Circuit breaker switching pulses:

1. **ZW-1** – W1 circuit breaker switching pulse,
2. **ZW-2** – W2 circuit breaker switching pulse,
3. **ZW-3** – W3 circuit breaker switching pulse,

B. Operational status signalling:

1. **BL** – Error or blocking signalling,
2. **GP** – Readiness for operations (RFO) („Live contact”),
3. **SS** – Synchronization start,
4. **UW** – Internal fault.

C. Control signal:

1. **OG** – Pulse signal increasing generator's rotations, operation depends on Reg and Bout setpoints (table 3.3 #22, 23)
2. **OD** – Pulse signal reducing generator's rotations, operation depends on Reg and Bout setpoints (table 3.3 #22, 23)
3. **NG** – Pulse signal increasing generator's voltage, operation depends on Reg and Bout setpoints (table 3.3 #22, 23)
4. **ND** – Pulse signal reducing generator's voltage, operation depends on Reg and Bout setpoints (table 3.3 #22, 23).

D. Selected bank number signalling signals:

1. **BN1** – Selected bank 1, operation depends on Reg and Bout setpoints (table 3.3 #22, 23),

2. **BN2** – Selected bank 2, operation depends on Reg and Bout setpoints (table 3.3 #22, 23),
3. **BN3** – Selected bank 3, operation depends on Reg and Bout setpoints (table 3.3 #22, 23),
4. **BN4** – Selected bank 4, operation depends on Reg and Bout setpoints (table 3.3 #22, 23).

3.5.2. Selection of active setpoint bank

Bank selection method depends on the Bimp setpoint (table 3.3 #21). If Bimp = 0, then bank is selected through supplying (and maintaining) voltage to one of the inputs Bank-1,...,Bank-4.

If Bimp = 1, bank is selected in a pulse mode. A prerequisite of correct bank selection in a pulse mode, is to give rising edge to the selected input Bank-1,...,Bank-4 in parallel to the lack of voltage at the remaining setpoint bank selections.

3.5.3. State of the switching station

State of switching station is understood as state of all monitored circuit breakers and disconnectors. As standard in 1,5-breaker switching station 3 circuit breakers and 2 disconnectors are installed.

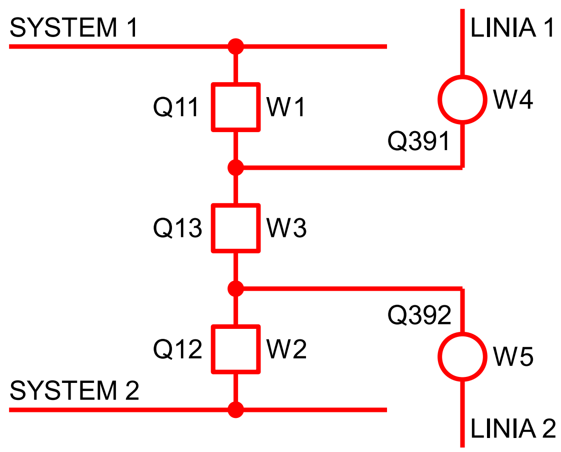

Fig. 3.5. Monitored switching devices in the switching station

3.5.4. Matrix of switching station states

Matrix of states contains all distinguished by synchronizer states of switching station, permissions for switching for given states of switching station and voltage pairs selected for switching. States omitted in the matrix are considered as forbidden and switching in such cases is not performed.

Matrix of switching states is prepared by producer. Configuration should be coordinated with designer of the switching station.

3.5.5. Synchronization in a system with switching

In the system where switching is used (measuring voltages, circuit breaker position status, measuring transformer fuse status) the supervised switching mode shall be used that is switched on using setpoint Kom (table 3.3 #30). Under this mode the synchronizer, after preparation of appropriate matrix for a certain design, may control the switching system and selected individually response times of circuit breakers and adjustments of phase shifts depending on selected (switched) synchronization bay.

3.5.6. Three-phase voltage control

There are two cases of three-phase voltage control:

The first case is when the voltage is treated as "healthy", which means that the root-mean-square (rms) value exceeds 65% Un (0.65 of the rated voltage value). Under such circumstances the following conditions are controlled:

- Direction of rotation;
- The rms value of individual voltages (three-phase voltage is regarded to be correct, when the rms value of voltage in all 3 phases is equal or higher than 0.65 Un, where Un – value of rated voltage);
- Half-opened angles among individual vectors of three-phase voltage (permissible half-opened angle shall range between 120° ± 10°).

The second case applies to the situation where voltage is treated as residual (e.g. voltage induced in a non-supplied line). Under such circumstances one condition is controlled:

- The rms value of voltage of all 3 phases has to be smaller or equal to 0.3 Un, where Un - rated voltage value.

Three-phase voltage control at relevant measuring inputs (U1,U2,U3,U4) is switched on and off using setpointsh (table 3.3 #16,17,18,19)

3.5.7. Selection of operation mode

Selecting the operating mode can occur automatically if the setting Atrb = 1 (table 3.3 #20). In this case, mode selection depends on fulfilled conditions, settings and selected settings bank. If the setting Atrb = 0 (table 3.3 #20) operation mode selection is performed by binary inputs SYN, ZSK, SBN, GBN i SGBN.

Acceptance of any given operation mode is connected with fulfilling of some conditions, characteristic for a given operation mode. It doesn't mean that closing of the breaker will be possible, because not all conditions are taken into consideration while establishing operation mode.

Conditions for acceptance of ZSK mode:

$$Uw \geq 60\,\%\,Un \quad (3.1)$$

$$Uo \geq 60\,\%\,Un \quad (3.2)$$

$$|dmx| \leq dr(.) \quad (3.3)$$

where:

Uw	– measured own voltage, phase 1;
Uo	– measured reference voltage, phase 1;
Un	– rated voltage;
dmx	– maximal measured drift of phase difference during time interval Tg(.) (table 3.1 #10);
dr(.)	– permissible drift of phase difference (table 3.1 #21);
Tg(.)	– boundary time for drift measurement (table 3.1 #22);
(.)	– depends on selected setting bank (Bank-1,...,Bank-4).

Conditions for acceptance of SYN mode:

$$Uw \geq 60\,\%\,Un \quad (3.4)$$

$$Uo \geq 60\,\%\,Un \quad (3.5)$$

$$|dmx| > dr(.) \quad (3.6)$$

where:

Uw	– measured own voltage, phase 1;
Uo	– measured reference voltage, phase 1;
Un	– rated voltage;
dmx	– maximal measured drift of phase difference during time interval Tg(.) (table 3.1 #10);
dr(.)	– permissible drift of phase difference (table 3.1 #21);
Tg(.)	– boundary time for drift measurement (table 3.1 #22);
(.)	– depends on selected setting bank (Bank-1,...,Bank-4).

Conditions for acceptance of SGBNmode:

$$Uw \leq 30\,\%\,Un \quad (3.7)$$

$$Uo \leq 30\,\%\,Un \quad (3.8)$$

where:

Uw	– measured own voltage, phase 1;
Uo	– measured reference voltage, phase 1;
Un	– rated voltage.

Conditions for acceptance of SBN mode:

Case 1:

$$Uw < 60\,\%\,Un \tag{3.9}$$

$$Uo > 60\,\%\,Un \tag{3.10}$$

Case 2:

$$Uw \leq 60\,\%\,Un \tag{3.11}$$

$$Uo \leq 60\,\%\,Un \tag{3.12}$$

$$Uo > 30\,\%\,Un \tag{3.13}$$

$$Uo > Uw \tag{3.14}$$

where:

Uw – measured own voltage, phase 1;

Uo – measured reference voltage, phase 1;

Un – rated voltage.

Conditions for acceptance of GBN mode:

Case 1:

$$Uw > 60\,\%\,Un \tag{3.15}$$

$$Uo < 60\,\%\,Un \tag{3.16}$$

Case 2:

$$Uw \leq 60\,\%\,Un \tag{3.17}$$

$$Uo \leq 60\,\%\,Un \tag{3.18}$$

$$Uw > 30\,\%\,Un \tag{3.19}$$

$$Uw \geq Uo \tag{3.20}$$

where:

Uw – measured own voltage, phase 1;

Uo – measured reference voltage, phase 1;

Un – rated voltage.

3.5.8. Start-up and turning off

Synchronizer is started by turning on power supply. After switching-on synchronizer performs an auto-test. If no internal errors are detected, synchronizer passes to stand-by status.

Synchronizer is provided with system for mains voltage check. If value of this voltage is below minimal value (given in technical specifications), device will pass to **emergency standstill** status.

Synchronizer can be turned off in any moment disconnecting mains voltage.

3.5.9. Emergency standstill

Emergency standstill occurs, when an error is detected, disabling proper execution of the selected switching operation.

Consequences of accidental standstill are:

1. Error signalling - closing of +BL and BL (relay contacts),
2. Appearance of error message on LCD display,
3. Alighting of error signalling LED.

If emergency standstill was caused by impossibility of completing of synchronization process, synchronizer will come back to **stand-by** status after about 2 seconds.

If emergency standstill was caused by mains voltage drop below minimal threshold required for normal operation, synchronizer will stay in emergency standstill status until mains voltage will recover to required minimal value.

3.5.10. Operation modes

In this chapter operation of the synchronizer in individual operation modes will be presented.

3.5.10.1. Automatic synchronization with constant lead time – SYN mode

With the **waiting status** (fig. 3.6) the system displays current rms values of measuring voltages **Uw** and **Uo** as % of rated values and their frequencies **fw** and **fo**.

In the first line the following information is displayed from left to right:

- operational mode status – e.g.: "SYN".
- selected setpoint bank information – e.g.: "B1" – setpoint bank No. 1
- information about selected generator – e.g.: "G1" – Generator No. 1
- information about correctness of three-phase voltages – e.g. "U1:R".
- information about correctness of three-phase voltages – e.g. "U3:R".

Information about correctness of three-phase voltage expressed as follows: „Uy:**x**", where:

- **x**: information about voltage may have the following values:
- "R" - correct three-phase voltage, voltage status (> 65% Un),
- "L" - Incorrect rotation, voltage status (> 65% Un),
- "0" - correct three-phase voltage, de-energized status (< 30% Un),
- "!" - incorrect three-phase voltage,
- „-" - uncontrolled three-phase voltage,
- "?" - no information from measuring unit.

The values of **Uw** voltage and **fw** frequency of own voltage are displayed in the second (using the example of fig. 3.6 it is U1 voltage and f1 frequency)

The values of **Uo** voltage and **fo** frequency of reference voltage are displayed in the third line (using the example of fig. 3.6 it is U3 voltage and f3 frequency)

In the last line the phase difference **dfi** is displayed, input status: BLKZ – **B** and information about synchronizer selection **W**. "**0**" – stands for inactive status, "**1**" – active

With the **waiting status** the synchronizer does not send any signals and retains this status until voltage has occurred on one of the START-x inputs. The voltage at START-x input, does not have to be maintained, only a pulse is required.

SYN	B1 G1	U1:R	U3:R
U1=102,3%		f1=50,05Hz	
U3= 99,7%		f3=49,72Hz	
dfi= 35°		W=0	B=0

Fig. 3.6 Waiting in SYN mode

3.5.10.1.1. Start of switching process in SYN mode

Applying of a voltage (active state) at activating input (selecting synchronizer for operation) is a necessary condition for starting synchronization process - depending on the setting 3WBR (table 3.3 #26)

$$WBR=1 \qquad (3.21)$$

Next necessary condition is:

Selected one and only one setting bank (3.22)

Synchronizer checks periodically state of monitored breakers connected to inputs W1,...,W8.

State of switching station understood as combination of state of all breakers W1,...,W8 should be included in matrix of states. In opposite case switching is impossible.

If state of switching station has been defined in matrix of permissible states, synchronizer checks, which breakers have been determined for this particular state of switching station as possible for closing.

Simultaneously the device checks which voltage pairs (U1-U2, U1-U3, U1-U4, U2-U1, U2-U3, U2-U4, U3-U4) have been determined as possible for using for given state of switching station.

If for selected voltage pair Ux-Uy state of inputs Ux_OK and Uy_OK is proper, synchronizer decides that switching by a given breaker is theoretically possible, assuming that criteria conditions are fulfilled.

First voltage from the selected pair Ux-Uy is then considered as own voltage (Uw). As reference voltage (Uo) is considered the second voltage from the selected pair.

As an example, for selected voltage pair U1-U3, own voltage Uw will be voltage connected to U1 terminals of X9 connector and reference voltage will be voltage connected to U3 terminals of connector X8.

In network solutions synchronizer has no possibilities to adjust voltage and frequency, so already at the beginning following conditions should be fulfilled:

$$-dU(.) \le dU \le +dU(.) \quad * \qquad (3.23)$$

$$-df(.) \le df \le +df(.) \quad * \tag{3.24}$$

$$Uwd(.) \le Uw \le Uwg(.) \tag{3.25}$$

$$Uod(.) \le Uo \le Uog(.) \tag{3.26}$$

*Correct three-phase voltage Uw*** (3.27)

*Correct three-phase voltage Uo*** (3.28)

$$BLKZ = 0 \tag{3.29}$$

*Only in case, when WarU = 1 (table 3.3 #24)

**Only in case, when three-phase voltage control is enabled (table 3.3 #16,17,18, 19)

where:

-dU(.)	– lower boundary value of voltage difference during synchronization (table 3.1 #1);
+dU(.)	– upper boundary value of voltage difference during synchronization (table 3.1 #2);
-df(.)	– permissible frequency difference at "upstream" switching (table 3.1 #3);
+df(.)	– permissible frequency difference at "downstream" switching (table 3.1 #4);
Uwd(.)	– lower boundary value of own voltage (table 3.1 #11);
Uwg(.)	– upper boundary value of own voltage (table 3.1 #12);
Uod(.)	– lower boundary value of reference voltage (table 3.1 #17);
Uog(.)	– upper boundary value of reference voltage (table 3.1 #18);
dU	– measured voltage difference;
df	– measured frequency difference;
Uw	– measured own voltage, phase 1;
Uo	– measured reference voltage, phase 1;
BLKZ	– state of "external locking" digital input
(.)	– depends on selected setting bank (Bank-1,...,Bank-4);

If all conditions are fulfilled, synchronizer will pass to **switching** state. In switching state it compares measured values to settings, adjusts generator voltage and angular speed (if it is possible) and closes circuit breaker with set time advance. During adjustment process, before switching, display presents information as in example shown in fig.. 3.7.

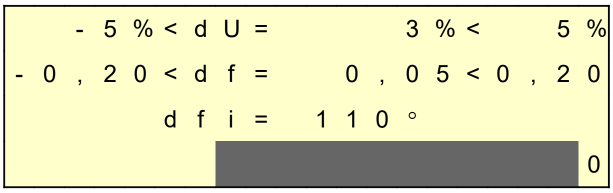

Fig. 3.7 Switichng in SYN mode

In central part of the LCD display, after „=”, symbol current measured values are displayed of voltage difference **dU**, frequency difference **df** and phase difference **dfi**. In left part of the display lower boundary values are displayed for voltages „**–dU**” (table 3.1, lp.1) and frequencies „**–df**”, (table 3.1, lp.3). In right part – corresponding upper boundary values „**+dU**” (table 3.1, lp.2) and „**+df**” (table 3.1, lp.4). Introducing as setting **„ZL-”** (table 3.2, lp.5)value „N” one can lock switching „from down” i.e. for dF < 0. In such case value 0 will be displayed in lace of selected value of -dF. Introducing as setting **„ZL+”** (table 3.2, lp.6) value „N” one can lock switching „from top” i.e. for dF > 0. In such case value 0 will be displayed in lace of selected value of +dF. In four row of the display absolute value of phase difference is presented in the form of black bar, in the scope from 0 to 180° with step ±2°. Zero value for the bar, corresponding to phase difference equal to **„0”** is located at right side of the display. Measured values are refreshed 25 times per second.

Voltage difference dU is presented as relative value:

$$dU = 100 \frac{Uo - Uw}{Uw} [\%] \tag{3.30}$$

Where:

Uw	– measured own voltage
Uo	– measured reference voltage

Frequency difference df is presented as relative value:

$$df = 100 \frac{fo - fw}{fw} [\%] \tag{3.31}$$

Gdzie:

fw	– measured frequency of own voltage
fo	– measured frequency of reference voltage

Phase difference dfi is presented in degrees:

$$dfi = fio - fiw [^\circ] \tag{3.32}$$

Gdzie:

fiw	– measured phase of own voltage
fio	– measured phase of reference voltage

If in state "switching" in any moment following inequality (3.33) will not be fulfilled

$$-15\% < df < 15\% \tag{3.33}$$

then synchronizer will pass to to **emergency standstill** state.

3.5.10.1.2. Voltage adjustment

Voltage adjustment signal is a pulse train of 1Hz frequency with adjusted duty cycle equal ww (table 3.2 #1). Synchronizer adjusts voltage at frequency difference |df| < dfu (table 3.2 #2).

If generator voltage does not depend on its angular velocity (table 3.2 #4, setting C = 0) and dU > (+dU/2) (table 3.1 #2) then synchronizer generates ND pulses decreasing generator voltage. If dU < (–dU/2) (table 3.1 #1) then synchronizer generates NG pulses increasing generator voltage. If during pulse ND condition dU > (+dU/2) is no longer fulfilled, then adjusting signal is broken. Similarly, if during pulse NG condition dU < (-dU/2) is no longer fulfilled, then adjusting signal NG is also broken. Pulses NG i ND are also broken after closing the circuit breaker.

In case when generator voltage depends on its angular velocity (table 3.2 #4, setting C ≠ 0) voltage adjustment is correlated with frequency adjustment. Pulses for voltage adjustment are modified in such way that in the moment when frequency conditions are fulfilled, simultaneously voltage conditions were also met.

In network synchronization voltage adjustment isn't used on account of the lack of possibility to influence of the synchronizer on switched power networks.
The control algorithm can be disabled by Reg setting (table 3.3 #22)

3.5.10.1.3. Adjustment of generator rotational speed

Synchronizer adjusts rotational speed of generator changing the setting of this speed in the controller of turbine, which propels this generator. Adjustment is performed by means of pulses of set time of duration TrF (table 3.2 #3), twice during each period of rumble voltage.

In network synchronization voltage adjustment isn't used on account of the lack of possibility to influence of the synchronizer on switched power networks.
The control algorithm can be disabled by Reg setting (table 3.3 #22)

3.5.10.1.4. Prevention synchronous and non-cophasal operation

If during 20s no pulse for rotational speed adjustment will be sent and in the same time absolute value of frequency difference is lower than 0.1%, then synchronizer sends a pulse causing generator exits state of synchronous non-cophasal operation.

3.5.10.1.5. Closing of circuit breaker in SYN mode

Synchronizer sends, with time advance set for the selected circuit breaker tw (table 3.3 #1,2,3,4), pulse **ZWx** (x = 1,2,3) turning on the circuit breaker only if there are simultaneously fulfilled following conditions for precise synchronization (3.34, 3.35 i 3.36):

$$-dU(.) \le dU \le +dU(.) \tag{3.34}$$

$$-df(.) \le df \le +df(.) \tag{3.35}$$

$$|dfi| \le fia \tag{3.36}$$

Some additional conditions (3.37 i 3.38) should be also fulfilled:

$$BLKZ = 0 \tag{3.37}$$

Min. 2 s passed since last rotational speed adjustment pulse was finished and no next pulse was started. (3.38)

where:

-dU(.)	– lower boundary value of voltage difference during synchronization (table 3.1 #1);
+dU(.)	– upper boundary value of voltage difference during synchronization (table 3.1 #2);
-df(.)	– permissible frequency difference at "upstream" switching (table 3.1 #3);
+df(.)	– permissible frequency difference at "downstream" switching (table 3.1 #4);
fia	– permissible angular deviation (table 3.1 #23);
dU	– measured voltage difference;
df	– measured frequency difference;
dfi	– anticipated phase difference (phase deviation) in the moment of closing contacts of circuit breaker;
(.)	– depends on selected setting bank (Bank-1,...,Bank-4);

If listed above conditions for synchronization with constant time advance are not fulfilled during current period of rumble voltage, synchronizer will wait if they will be fulfilled in next period and so on, unless permissible expectation time for synchronization **Tmax** expires (table 3.1 #24).

External locking signal BLKZ will lock the signal turning on circuit breaker if it arises before ZW signal. In opposite case once started turning on signal will ast during time:

$$tzw \leq tw + 300\,ms \tag{3.39}$$

gdzie:

tw	– set advance time;

and is broken in the moment of confirmation of "unequivocally closed state" obtained from auxiliary contacts of circuit breaker.

Pulse turning on the circuit breaker can be single, if setting Lp = 1 (table 3.1 #25), or multiple, when Lp > 1 and signal confirming closed state of circuit breaker is lacking.

If Lp > 1 and after starting **ZW** pulse turning on the circuit breaker during time **tzw** no signals come from auxiliary contacts confirming unequivocally closed state then synchronizer will try again to perform switching until the set number of attempts will be applied.

S Y N	B 1	G 1	O D S T _ P P
U 1 = 1 0 0 , 2 %		f 1 = 5 0 , 0 0 H z	
U 3 = 1 0 0 , 2 %		f 3 = 5 0 , 0 0 H z	
d f i =	0 °		

Fig. 3.8 Switching confirmation in SYN mode

If during some next attempt successful switching will occur, confirmed by signals from circuit breaker. then synchronizer will pass to **standstill** after on (fig. 3.8). In **standstill** after on state display presents current values of measured voltages **Uw** and **Uo**, (in % of rating value, in example voltage pair U1-U3 is shown), frequencies **fw** and **fo** and phase difference **dfi**.

If Lp = n and during n-th pulse **ZW**, signals from auxiliary contacts of circuit breaker confirming unequivocally closed state are lacking, synchronizer passes to **emergency standstill** state (fig. 3.9).

O D S T A W I E N I E	1		
U 1 = 1 0 0 , 2 %		f 1 = 5 0 , 0 0 H z	
U 3 = 1 0 0 , 2 %		f 3 = 5 0 , 0 0 H z	
d f i =	5 3 , 3 2 °		* * * *

Fig. 3.9 Unsuccessful synchronization

✶✶✶✶ indicate that measured angle is the real angle of phase shift between measured voltages connected to synchronizer inputs, (without correction by constant phase shift).

Irrespective of the reason of standstill, after about 2 seconds synchronizer comes back to stand-by status.

Settings fi1, ... ,fi7 (table 3.3, #5,6,7,8,9,10,11) enable correction of constant phase shift between measuring inputs as "seen" by synchronizer. It is useful in situation, when as a result of phase shifts caused by measuring transformers or transformers phase difference at measuring terminals isn't equal to phase difference at both sides of circuit breaker. If such phase shifts don't exist, those settings should be set to 0.

3.5.10.1.6. Interruption of the switching process in SYN mode

The synchronizer will automatically go into **emergency shutdown status**, if during the switching status, at any time one of the conditions specified below has not been met:

$$Uwd(.) \le Uw \le Uwg(.) \qquad (3.40)$$

$$Uod(.) \le Uo \le Uog(.) \qquad (3.41)$$

$$-15\% < df < +15\% \qquad (3.42)$$

*Correct three-phase voltage Uw** (3.43)

*Correct three-phase voltage Uo** (3.44)

$$t < Tmax(.) \qquad (3.45)$$

*Only in case, when three-phase voltage control is enabled (table 3.3 #16,17,18, 19)

where:

Uwd(.)	– lower limit of own voltage (table 3.1 #11);
Uwg(.)	– upper limit of own voltage (table 3.1 #12);
Uod(.)	– lower limit of reference voltage (table 3.1 #17);
Uog(.)	– upper limit of reference voltage (table 3.1 #18);
Tmax(.)	– maximum time of switching process (table 3.1 #24);
df	– measured frequency difference (according to 3.31);
Uw	– rms value of measured voltage Uw, phase 1;
Uo	– rms value of measured voltage Uo, phase 1;
t	– time that elapsed from the start of switching process;
(.)	– depends on selected setpoint bank (Bank-1,...,Bank-4);

The synchronizer may also automatically go into **emergency shutdown status**, if during the switching status, at any time, the status of any of the inputs has changed:

- W1o,W2o,...,W8o,
- W1z,W2z,...,W8z,
- BANK1, BANK2, BANK3, BANK4,
- WBRx,
- STOP.

Regardless of the shutdown cause the synchronizer goes back to the waiting time once the registration has been completed.

3.5.10.2. Switching in pre-set angular sector – ZSK mode

In **stand-by** status (fig. 3.10) current values of voltage difference **dU**, phase difference **df**i and current drift **fsr** and maximal drift **fmx** in time period Tg are displayed.

In the first line the following information is displayed from left to right:

- operational mode status – e.g.: "ZSK".
- selected setpoint bank information – e.g.: "B1" – setpoint bank No. 1
- information about correctness of three-phase voltages – e.g. "U1:R".
- information about correctness of three-phase voltages – e.g. "U3:R".

Information about correctness of three-phase voltage expressed as follows: „Uy:**x**", where:

- **x**: information about voltage may have the following values:
- "R" - correct three-phase voltage, voltage status (> 65% Un),
- "L" - Incorrect rotation, voltage status (> 65% Un),
- "0" - correct three-phase voltage, de-energized status (< 30% Un),
- "!" - incorrect three-phase voltage,
- „-" - uncontrolled three-phase voltage,

–"?" - no information from measuring unit.

```
ZSK    B1     U1: R  U3: R
  -5%<dU=      2%<    5%
-30°<dfi=    13°<   30°
dsr=    0,2  dmx=    0,9
```

Fig. 3.10 Stand-by status in ZSK mode

In each 0,5s time period maximal value of drift „fmx” is computed on the basis of 50 measurements performed each 10 ms. Last measured maximal value fmx determined within time period Tg and current frequency difference fsr are displayed on LCD. Values of voltage difference dU and phase difference dfi are updated on the display 25 times per second.

Phase difference drift is displayed with resolution 0.1 [°/s], corresponding frequency difference 0.277(7) mHz. Moreover result of drift measurement is available in digital form with resolution 0.01 [°/s], corresponding frequency difference 27.777(7) μHz. Such accurate measurement if of key importance at switching power networks between which there is only slight slip (frequency difference is close to zero). Criterion enabling switching process is maximal value of phase drift in the set time period. Such attempt allows to eliminate accidental switching of networks, when average frequency difference is small, but phase jumps are appearing.

3.5.10.2.1. Start of switching process in ZSK mode

Applying of a voltage (active state) at activating input (selecting synchronizer for operation) is a necessary condition for starting synchronization process - depending on the setting 3WBR (table 3.2 #26)

$$WBR=1 \tag{3.46}$$

Next necessary condition is:

Selected one and only one setting bank (3.47)

Synchronizer checks periodically state of monitored breakers connected to inputs W1,...,W8.

State of switching station understood as combination of state of all breakers W1,...,W8 should be included in matrix of states. In opposite case switching is impossible.

If state of switching station has been defined in matrix of permissible states, synchronizer checks, which breakers have been determined for this particular state of switching station as possible for closing.

Simultaneously the device checks which voltage pairs (U1-U2, U1-U3, U1-U4, U2-U1, U2-U3, U2-U4, U3-U4) have been determined as possible for using for given state of switching station.

If for selected voltage pair Ux-Uy state of inputs Ux_OK and Uy_OK is proper, synchronizer decides that switching by a given breaker is theoretically possible, assuming that criteria conditions are fulfilled.

First voltage from the selected pair Ux-Uy is then considered as own voltage (Uw). As reference voltage (Uo) is considered the second voltage from the selected pair.

As an example, for selected voltage pair U1-U3, own voltage Uw will be voltage connected to U1 terminals of X9 connector and reference voltage will be voltage connected to U3 terminals of connector X8.

So that impulse at chosen START-x input could start the switching process, following conditions should be met:

$$Uwd(.) \le Uw \le Uwg(.) \quad (3.48)$$

$$Uod(.) \le Uo \le Uog(.) \quad (3.49)$$

$$dUd(.) \le dU \le dUg(.) \;\; * \quad (3.50)$$

$$-dfi(.) \le dfi \le +dfi(.) \;\; * \quad (3.51)$$

$$|dmx| \le dr(.) \;\; * \quad (3.52)$$

*Correct three-phase voltage Uw*** (3.53)

*Correct three-phase voltage Uo*** (3.54)

$$BLKZ = 0 \quad (3.55)$$

*Only in case, when WarU = 1 (table 3.3 #24)

** Only in case, when three-phase voltage control is enabled (table 3.3 #16,17,18, 19)

where:

Uwd(.)	– lower boundary value of own voltage (table 3.1 #11);
Uwg(.)	– upper boundary value of own voltage (table 3.1 #12);
Uod(.)	– lower boundary value of reference voltage (table 3.1 #17);
Uog(.)	– upper boundary value of reference voltage (table 3.1 #18);
dUd(.)	– permissible frequency difference at "from down" switching (table 3.1 #7);
dUg(.)	– permissible frequency difference at "from up" switching (table 3.1 #8);
-dfi(.)	– lower boundary value of phase difference (table 3.1 #5);
dfi(.)	– upper boundary value of phase difference (table 3.1 #6);
Tg(.)	– boundary time for drift measurement (table 3.1 # 10);
dr(.)	– permissible drift of phase difference (table 3.1 #9);
Uw	– measured value of own voltage, phase 1;
Uo	– measured value of reference voltage, phase 1;
dU	– measured voltage difference;
dfi	– measured phase difference;
dmx	– maximal value of phase difference drift measured within time period Tg(.);
BLKZ	– state of "external locking" digital input;
(.)	– depends on selected setting bank (Bank-1,...,Bank-4);

If all conditions are fulfilled, synchronizer will pass to **drift measurement state.** In this state synchronizer once more checks maximal drift within the set time period Tg. Information as shown in example in fig. 3.11 is displayed.

```
ZSK   POMIAR
  -5%<dU=    2%<  5%
-30°<dfi=   13°< 30°
             W=1  B=0
```

Fig. 3.11 Switching in ZSK mode

3.5.10.2.2. Closing of circuit breaker in ZSK mode

After expiry of time Tg synchronizer checks again conditions 3.48, 3.49, 3.50, 3.51, 3.52, 3.54, 3.55 and if switching was successful and has been acknowledged by signals coming from circuit breaker, then synchronizer passes to **standstill** after on state (fig. 3.12). In **standstill** after on state display presents current values of measured voltages **Uw** and **Uo**, (in % of rating value, in example voltage pair U1-U3 is shown), frequencies **Fw** i **Fo** and phase difference **dfi**.

```
ZSK   B1     ODST_PP
U1=100,2%  f1=50,00Hz
U3=100,2%  f3=50,00Hz
dfi=    1°
```

Fig. 3.12 Switching confirmation in ZSK mode

If any of conditions 3.50, 3.51, 3.52 isn't fulfilled after time Tg expires, the synchronizer starts waiting for meeting these requirements (fig. 3.13). Maximal time of waiting for meeting conditions is determined by setting Tmax (table 3.1 #24).

```
dsr=   0,2   dmx=   0,9
  -5%<dU=    2%<  5%
-30°<dfi=   13°< 30°
 OCZEK.  NA  WARUNKI
```

Fig. 3.13 Waiting for conditions in ZSK mode

If during time Tmax all conditions are not met, synchronizer will pass to standstill state. Similar behaviour arises when during attempt to close circuit breaker there is lack of signals coming from auxiliary contacts of the breaker, confirming unequivocally closed state.

```
ODSTAWIENIE     1
U1=  98,2%  F1=50,03Hz
U3=100,2%  F3=49,99Hz
dfi=      12,18°  ****
```

Fig. 3.14 Unsuccessful synchronization

✶✶✶✶ arising in the last line indicate that measured angle is the real angle of phase shift between measured voltages connected to synchronizer inputs, (without correction by constant phase shift).

Irrespective of the reason of standstill, after about 2 seconds synchronizer comes back to stand-by status.

Settings fi1, … ,fi7 (table 3.3 #5,6,7,8,9,10,11) enable correction of constant phase shift between measuring inputs as "seen" by synchronizer. It is useful in situation, when as a result of phase shifts caused by measuring transformers or transformers phase difference at measuring terminals isn't equal to phase difference at both sides of circuit breaker. If such phase shifts don't exist, those settings should be set to 0.

3.5.10.2.3. Interruption of the switching process in ZSK mode

The synchronizer will automatically go into **emergency shutdown status**, if during the switching status, at any time one of the conditions specified below has not been met:

$$Uwd(.) \leq Uw \leq Uwg(.) \tag{3.56}$$

$$Uod(.) \leq Uo \leq Uog(.) \tag{3.57}$$

*Correct three-phase voltage Uw** (3.58)

*Correct three-phase voltage Uo** (3.59)

$$t < Tmax(.) \tag{3.60}$$

* Only in case, when three-phase voltage control is enabled (table 3.3 #16,17,18, 19)

where:

Uwd(.)	– lower boundary value of own voltage (table 3.1 #11);
Uwg(.)	– upper boundary value of own voltage (table 3.1 #12);
Uod(.)	– lower boundary value of reference voltage (table 3.1 #17);
Uog(.)	– upper boundary value of reference voltage (table 3.1 #18);
Tmax(.)	– maximum time of switching process a (table 3.1 #24);
Uw	– measured own voltage, phase 1;
Uo	– measured reference voltage, phase 1;
t	– time that elapsed from the start of switching process;
(.)	– depends on selected setting bank (Bank-1,...,Bank-4);

The synchronizer may also automatically go into **emergency shutdown status**, if during the switching status, at any time, the status of any of the inputs has changed:

- W1o,W2o,...,W8o,
- W1z,W2z,...,W8z,
- BANK1, BANK2, BANK3, BANK4,
- WBRx,
- STOP.

Regardless of the shutdown cause the synchronizer goes back to the waiting time once the registration has been completed.

3.5.10.3. Switching without own voltage – SBN mode

In **stand-by** status (fig. 3.15) the system displays current rms values of measuring voltages **Uw** and **Uo** as % of rated values and their frequencies **fw** and **fo**.

In the first line the following information is displayed from left to right:

- operational mode status – e.g.: "SBN".
- selected setpoint bank information – e.g.: "B1" – setpoint bank No. 1
- information about selected generator – e.g.: "G1" – Generator No. 1
- information about correctness of three-phase voltages – e.g. "U1:0".
- information about correctness of three-phase voltages – e.g. "U3:R".

Information about correctness of three-phase voltage expressed as follows: „Uy:**x**", where:

- **x**: information about voltage may have the following values:
- "R" - correct three-phase voltage, voltage status (> 65% Un),
- "L" - Incorrect rotation, voltage status (> 65% Un),
- "0" - correct three-phase voltage, de-energized status (< 30% Un),
- "!" - incorrect three-phase voltage,
- „-" - uncontrolled three-phase voltage,
- "?" - no information from measuring unit.

```
SBN   B1  G1  U1:0  U3:R
U1=   7,1%  F1=-----Hz
U3=100,2%  F3=50,00Hz
WBR=1       BLKZ=0
```

Fig. 3.15. Waiting in SBN mode

The values of **Uw** voltage and **fw** frequency of own voltage are displayed in the second (using the example of fig. 3.15 it is U1 voltage and f1 frequency)

Because typical state for SBN mode is lack of own voltage (or residual values) frequency measurement in such state isn't possible.

The values of **Uo** voltage and **fo** frequency of reference voltage are displayed in the third line (using the example of fig. 3.15 it is U3 voltage and f3 frequency)

In the last line input status: **BLKZ** and information about synchronizer selection **WBR** are displayed. "**0**" – stands for inactive status, "**1**" – active

With the **waiting status** the synchronizer does not send any signals and retains this status until voltage has occurred on one of the START-x inputs. The voltage at START-x input, does not have to be maintained, only a pulse is required.

3.5.10.3.1. Start of switching process in SBN mode

Applying of a voltage (active state) at activating input (selecting synchronizer for operation) is a necessary condition for starting synchronization process - depending on the setting 3WBR (table 3.3 #26)

$$WBR=1 \tag{3.61}$$

Next necessary condition is:

Selected one and only one setting bank (3.62)

Synchronizer checks periodically state of monitored breakers connected to inputs W1,...,W8.

State of switching station understood as combination of state of all breakers W1,...,W8 should be included in matrix of states. In opposite case switching is impossible.

If state of switching station has been defined in matrix of permissible states, synchronizer checks, which breakers have been determined for this particular state of switching station as possible for closing.

Simultaneously the device checks which voltage pairs (U1-U2, U1-U3, U1-U4, U2-U1, U2-U3, U2-U4, U3-U4) have been determined as possible for using for given state of switching station.

If for selected voltage pair Ux-Uy state of inputs Ux_OK and Uy_OK is proper, synchronizer decides that switching by a given breaker is theoretically possible, assuming that criteria conditions are fulfilled.

First voltage from the selected pair Ux-Uy is then considered as own voltage (Uw). As reference voltage (Uo) is considered the second voltage from the selected pair.

As an example, for selected voltage pair U1-U3, own voltage Uw will be voltage connected to U1 terminals of X9 connector and reference voltage will be voltage connected to U3 terminals of connector X8.

So that impulse at chosen START-x input could start the switching process, following conditions should be met:

$$Uod(.) \le Uo \le Uog(.) \tag{3.63}$$

$$fod(.) \le fo \le fog(.) \tag{3.64}$$

$$Uswd(.) \le Uw \le Uswg(.) \; * \tag{3.65}$$

*Correct three-phase voltage Uw*** (3.66)

*Correct three-phase voltage Uo*** (3.67)

$$BLKZ=0 \tag{3.68}$$

*Only in case, when War0 = 1 (table 3.3 #25)

**Only in case, when three-phase voltage control is enabled (table 3.3 #16,17,18, 19)

where:

Uod(.)	– lower boundary value of reference voltage (table 3.1 #17);
Uog(.)	– upper boundary value of reference voltage (table 3.1 #18);
fod(.)	– lower boundary value of reference voltage frequency (table 3.1 #19);
fog(.)	– upper boundary value of reference voltage frequency (table 3.1 #20);

Uswd(.)	– lower boundary value of own voltage (residual) (table 3.1 #15);
Uswg(.)	– upper boundary value of own voltage (residual) (table 3.1 #16);
Uw	– measured value of own voltage, phase 1;
Uo	– measured value of reference voltage, phase 1;
fo	– measured frequency for reference voltage;
BLKZ	– state of "external locking" digital input;
(.)	– depends on selected setting bank (Bank-1,...,Bank-4);

3.5.10.3.2. Closing of circuit breaker in SBN mode

If conditions 3.63, 3.64, 3.65, 3.66 i 3.68 are fulfilled synchronizer sends signal ZW closing the circuit breaker. If switching was successful and was confirmed by signals coming from circuit breaker, synchronizer passes to **standstill** after on (fig. 3.16). In **standstill** after on state display presents current values of measured voltages **Uw** i **Uo**, (in % of rating value, in example voltage pair U1-U3 is shown), frequencies **Fw** and **Fo** and phase difference **dfi**.

```
SBN    B1  G1  ODST_PP
U1=100,2%  f1=50,00Hz
U3=100,2%  f3=50,00Hz
dfi=     0°
```

Fig. 3.16 Switching confirmation in SBN mode

If there is lack of signals from auxiliary contacts of the breaker, confirming unequivocally closed state, synchronizer passes to **emergency standstill** state.

```
ODSTAWIENIE      1
U1=   7,1%  F1=-----Hz
U3=100,2%  F3=50,00Hz
faza nieokreślona
```

Fig. 3.17 Unsuccessful switching

✶✶✶✶ arising in the last line indicate that measured angle is the real angle of phase shift between measured voltages connected to synchronizer inputs, (<u>without correction by constant phase shift</u>).

Irrespective of the reason of standstill, after about 2 seconds synchronizer comes back to stand-by status.

Settings fi1, … ,fi7 (table 3.3 #5,6,7,8,9,10,11) enable correction of constant phase shift, which is "seen" by synchronizer between measuring inputs. It is useful in situation, when as a result of phase shifts caused by measuring transformers or transformers phase difference at measuring terminals isn't equal to phase difference at both sides of circuit breaker. If such phase shifts don't exist, those settings should be set to 0.

If any of conditions 3.63, 3.64, 3.65 isn't fulfilled and setting War0 = 0 (table 3.3 #25) the synchronizer starts waiting for meeting these requirement (fig. 3.18). Maximal time of waiting for meeting conditions is determined by setting Tmax (table 3.1 #24).

```
U1:  2,5<  14,3%<10,0
U3: 90,0<  99,9%<110,0
 47,50<49,99Hz<52,50
 OCZEK.  NA  WARUNKI
```

Fig. 3.18. Waiting for conditions in SBN mode

In the example (fig. 3.18) condition 3.65 isn't fulfilled (value of residual voltage U1 is out of the specified range).

If during time Tmax all conditions are not met, synchronizer will pass to standstill state (fig. 3.19)

```
ODSTAWIENIE    20: 65
U1=  14,3%  f1=-----Hz
U3=  99,9%  f3=49,99Hz
faza  nieokreślona
```

Fig. 3.19 Unsuccessful synchronization

Code of unsuccessful synchronization's reason along with optional details is shown in the upper right corner of the display.

Regardless of the shutdown cause the synchronizer goes back to the waiting time once the registration has been completed.

3.5.10.3.3. Interruption of the switching process in SBN mode

The synchronizer will automatically go into **emergency shutdown status**, if during the switching status, at any time one of the conditions specified below has not been met:

$$Uo \le Uog(.) \quad (3.69)$$

$$Uw \le Uwg(.) \quad (3.70)$$

*Correct three-phase voltage Uw** (3.71)

*Correct three-phase voltage Uo** (3.72)

$$t < Tmax(.) \quad (3.73)$$

* Only in case, when three-phase voltage control is enabled (table 3.3 #16,17,18,19)

where:

Uwg(.)	– upper limit of own voltage (table 3.1 #12);
Uog(.)	– upper limit of reference voltage (table 3.1 #18);
Tmax(.)	– maximum time of switching process (table 3.1 #24);
t	– time that elapsed from the start of switching process
Uw	– rms value of measured voltage Uw, phase 1;
Uo	– rms value of measured voltage Uo, phase 1;
(.)	– depends on selected setpoint bank (Bank-1,...,Bank-4);

The synchronizer may also automatically go into **emergency shutdown status**, if during the switching status, at any time, the status of any of the inputs has changed:

- W1o,W2o,...,W8o,
- W1z,W2z,...,W8z,
- BANK1, BANK2, BANK3, BANK4,
- WBRx,
- STOP.

Regardless of the shutdown cause the synchronizer goes back to the waiting time once the registration has been completed.

3.5.10.4. Switching without reference voltage – GBN mode

In **stand-by** state (fig. 3.20) current rms values of measuring voltages are displayed **Uw** and **Uo** in % of rated value together with their frequencies **fw** and **fo**.

In the first line the following information is displayed from left to right:

- operational mode status – e.g.: "GBN".
- selected setpoint bank information – e.g.: "B1" – setpoint bank No. 1
- information about selected generator – e.g.: "G1" – Generator No. 1
- information about correctness of three-phase voltages – e.g. "U1:R".
- information about correctness of three-phase voltages – e.g. "U3:0".

Information about correctness of three-phase voltage expressed as follows: „Uy:**x**", where:

- **x**: information about voltage may have the following values:
- "R" - correct three-phase voltage, voltage status (> 65% Un),
- "L" - Incorrect rotation, voltage status (> 65% Un),
- "0" - correct three-phase voltage, de-energized status (< 30% Un),
- "!" - incorrect three-phase voltage,
- „-" - uncontrolled three-phase voltage,
- "?" - no information from measuring unit.

The values of **Uw** voltage and **fw** frequency of own voltage are displayed in the second (using the example of fig. 3.20 it is U1 voltage and f1 frequency)

The values of **Uo** voltage and **fo** frequency of reference voltage are displayed in the third line (using the example of fig. 3.20 it is U3 voltage and f3 frequency)

Because typical state for GBN mode is lack of reference voltage (or residual values) frequency measurement in such state isn't possible.

In the last line input status: **BLKZ** and information about synchronizer selection **WBR** are displayed. "**0**" – stands for inactive status, "**1**" – active

With the **waiting status** the synchronizer does not send any signals and retains this status until voltage has occurred on one of the START-x inputs. The voltage at START-x input, does not have to be maintained, only a pulse is required.

GBN	B1 G1	U1:R	U3:0
U1=100,1%		f1=50,00Hz	
U3= 6,2%		f3=------Hz	
WBR=1		BLKZ=0	

Fig. 3.20. Waiting in GBN mode

3.5.10.4.1. Start of switching process in GBN mode

Applying of a voltage (active state) at activating input (selecting synchronizer for operation) is a necessary condition for starting synchronization process - depending on the setting 3WBR (table 3.3 #26)

$$WBR=1 \tag{3.74}$$

Next necessary condition is:

Selected one and only one setting bank (3.75)

Synchronizer checks periodically state of monitored breakers connected to inputs W1,...,W8.

State of switching station understood as combination of state of all breakers W1,...,W8 should be included in matrix of states. In opposite case switching is impossible.

If state of switching station has been defined in matrix of permissible states, synchronizer checks, which breakers have been determined for this particular state of switching station as possible for closing.

Simultaneously the device checks which voltage pairs (U1-U2, U1-U3, U1-U4, U2-U1, U2-U3, U2-U4, U3-U4) have been determined as possible for using for given state of switching station.

If for selected voltage pair Ux-Uy state of inputs Ux_OK and Uy_OK is proper, synchronizer decides that switching by a given breaker is theoretically possible, assuming that criteria conditions are fulfilled.

First voltage from the selected pair Ux-Uy is then considered as own voltage (Uw). As reference voltage (Uo) is considered the second voltage from the selected pair.

As an example, for selected voltage pair U1-U3, own voltage Uw will be voltage connected to U1 terminals of X9 connector and reference voltage will be voltage connected to U3 terminals of connector X8.

So that impulse at chosen START-x input could start the switching process, following conditions should be met:

$$Uwd(.) \leq Uw \leq Uwg(.) \tag{3.76}$$

$$fwd(.) \leq fw \leq fwg(.) \tag{3.77}$$

$$Usod(.) \leq Uo \leq Usog(.) \quad * \tag{3.78}$$

*Correct three-phase voltage Uw*** (3.79)

*Correct three-phase voltage Uo*** (3.80)

$$BLKZ = 0 \tag{3.81}$$

*Only in case, when War0 = 1 (table 3.3 #26)

**Only in case, when three-phase voltage control is enabled (table 3.3 #16,17,18,19)

where:

Uwd(.)	– lower boundary value of own voltage (table 3.1 #11);
Uwg(.)	– upper boundary value of own voltage (table 3.1 #12);
fwd(.)	– lower boundary value of own voltage frequency (table 3.1 #13);
fwg(.)	– upper boundary value of own voltage frequency (table 3.1 #14);
Usod(.)	– lower boundary value of reference voltage (residual) (table 3.1 #21);
Usog(.)	– upper boundary value of reference voltage (residual) (table 3.1 #22);
Uo	– measured value of reference voltage, phase 1;
Uw	– measured value of own voltage, phase 1;
fw	– measured frequency for own voltage;
BLKZ	– state of "external locking" digital input;
(.)	– depends on selected setting bank (Bank-1,...,Bank-4);

3.5.10.4.2. Closing of circuit breaker in SBN mode

If conditions 3.76, 3.77, 3.78, 3.79, 3.80 i 3.81 are fulfilled synchronizer sends signal ZW closing the circuit breaker. If switching was successful and was confirmed by signals coming from circuit breaker, synchronizer passes to **standstill** after on (fig. 3.21). In **standstill** after on state display presents current values of measured voltages **Uw** i **Uo**, (in % of rating value, in example voltage pair U1-U3 is shown), frequencies **Fw** and **Fo** and phase difference **dfi**.

GBN B1 G1 ODST_PP
U1=100,1% f1=50,00Hz
U3=100,1% f3=50,00Hz
fig-fis= 0°

Fig. 3.21 Switching confirmation in GBN mode

If there is lack of signals from auxiliary contacts of the breaker, confirming unequivocally closed state, synchronizer passes to **emergency standstill** state.

```
ODSTAWIENIE     1
U1=100,1%  f1=50,00Hz
U3=   6,2%  f3=------Hz
faza  nieokreślona
```

Fig. 3.22 Unsuccessful switching

✶✶✶✶ arising in the last line indicate that measured angle is the real angle of phase shift between measured voltages connected to synchronizer inputs, (without correction by constant phase shift).

Irrespective of the reason of standstill, after about 2 seconds synchronizer comes back to stand-by status.

Settings fi1, … ,fi7 (table 3.3 #5,6,7,8,9,10,11) enable correction of constant phase shift, which is "seen" by synchronizer between measuring inputs. It is useful in situation, when as a result of phase shifts caused by measuring transformers or transformers phase difference at measuring terminals isn't equal to phase difference at both sides of circuit breaker. If such phase shifts don't exist, those settings should be set to 0.

If any of conditions 3.76, 3.77, 3.78 isn't fulfilled and setting War0 = 0 (table 3.3 #25) the synchronizer starts waiting for meeting these requirement (fig. 3.23). Maximal time of waiting for meeting conditions is determined by setting Tmax (table 3.1 #24).

```
U3:  2,5<   1,7%<10,0
U1:90,0<102,1%<110,0
 47,50<50,02Hz<52,50
 OCZEK.  NA  WARUNKI
```

Fig. 3.23. Waiting for conditions in GBN mode

In the example (fig. 3.23) conditions 3.76 isn't fulfilled.

If during time Tmax all conditions are not met, synchronizer will pass to standstill state (fig. 3.24)

```
ODSTAWIENIE    20: 35
U1=102,1%  f1=50,02Hz
U3=   1,7%  f3=------Hz
faza  nieokreślona
```

Fig. 3.24 Unsuccessful synchronization

Code of unsuccessful synchronization's reason along with optional details is shown in the upper right corner of the display.

Regardless of the shutdown cause the synchronizer goes back to the waiting time once the registration has been completed.

3.5.10.4.3. Interruption of the switching process in GBN mode

The synchronizer will automatically go into **emergency shutdown status**, if during the switching status, at any time one of the conditions specified below has not been met:

$$Uo \leq Uog(.) \tag{3.82}$$

$$Uw \leq Uwg(.) \tag{3.83}$$

*Correct three-phase voltage Uw** (3.84)

*Correct three-phase voltage Uo** (3.85)

$$t < Tmax(.) \tag{3.86}$$

* Only in case, when three-phase voltage control is enabled (table 3.3 #16,17,18,19)

where:

Uwg(.)	– upper limit of own voltage (table 3.1 #12);
Uog(.)	– upper limit of reference voltage (table 3.1 #18);
Tmax(.)	– maximum time of switching process (table 3.1 #24);
t	– time that elapsed from the start of switching process
Uw	– rms value of measured voltage Uw, phase 1;
Uo	– rms value of measured voltage Uo, phase 1;
(.)	– depends on selected setpoint bank (Bank-1,...,Bank-4);

The synchronizer may also automatically go into **emergency shutdown status**, if during the switching status, at any time, the status of any of the inputs has changed:

- W1o,W2o,...,W8o,
- W1z,W2z,...,W8z,
- BANK1, BANK2, BANK3, BANK4,
- WBRx,
- STOP.

Regardless of the shutdown cause the synchronizer goes back to the waiting time once the registration has been completed.

3.5.10.5. Switching without both voltages – SGBN mode

In **stand-by** state (fig. 3.25) current rms values of measuring voltages are displayed **Uw** and **Uo** in % of rated value together with their frequencies **fw** and **fo**.

In the first line the following information is displayed from left to right:

- operational mode status – e.g.: "SGBN”.
- selected setpoint bank information – e.g.: "B1” – setpoint bank No. 1
- information about selected generator – e.g.: "G1” – Generator No. 1

- information about correctness of three-phase voltages – e.g. "U1:0”.
- information about correctness of three-phase voltages – e.g. "U3:0”.

Information about correctness of three-phase voltage expressed as follows: „Uy:**x**”, where:

- **x**: information about voltage may have the following values:
- "R” - correct three-phase voltage, voltage status (> 65% Un),
- "L” - Incorrect rotation, voltage status (> 65% Un),
- "0” - correct three-phase voltage, de-energized status (< 30% Un),
- "!” - incorrect three-phase voltage,
- „-” - uncontrolled three-phase voltage,

"?” - no information from measuring unit.

The values of **Uw** voltage and **fw** frequency of own voltage are displayed in the second (using the example of fig. 3.25 it is U1 voltage and f1 frequency)

The values of **Uo** voltage and **fo** frequency of reference voltage are displayed in the third line (using the example of a fig. 3.25 it is U3 voltage and f3 frequency)

Because typical state for SGBN mode is lack of reference voltage (or residual values) frequency measurement in such state isn't possible.

In the last line input status: **BLKZ** and information about synchronizer selection **WBR** are displayed. "**0**” – stands for inactive status, "**1**” – active

With the **waiting status** the synchronizer does not send any signals and retains this status until voltage has occurred on one of the START-x inputs. The voltage at START-x input, does not have to be maintained, only a pulse is required.

SGBN	B1	G1	U1:0 U3:0
U1=	4,6%	F1=-----Hz	
U3=	6,2%	F3=-----Hz	
WBR=1		BLKZ=0	

Fig. 3.25. Stand-by in SGBN mode

3.5.10.5.1. Start of switching process in SGBN mode

Applying of a voltage (active state) at activating input (selecting synchronizer for operation) is a necessary condition for starting synchronization process - depending on the setting 3WBR (table 3.3 #26)

$$WBR=1 \tag{3.87}$$

Next necessary condition is:

Selected one and only one setting bank (3.88)

Synchronizer checks periodically state of monitored breakers connected to inputs W1,...,W8.

State of switching station understood as combination of state of all breakers W1,...,W8 should be included in matrix of states. In opposite case switching is impossible.

If state of switching station has been defined in matrix of permissible states, synchronizer checks, which breakers have been determined for this particular state of switching station as possible for closing.

Simultaneously the device checks which voltage pairs (U1-U2, U1-U3, U1-U4, U2-U1, U2-U3, U2-U4, U3-U4) have been determined as possible for using for given state of switching station.

If for selected voltage pair Ux-Uy state of inputs Ux_OK and Uy_OK is proper, synchronizer decides that switching by a given breaker is theoretically possible, assuming that criteria conditions are fulfilled.

First voltage from the selected pair Ux-Uy is then considered as own voltage (Uw). As reference voltage (Uo) is considered the second voltage from the selected pair.

As an example, for selected voltage pair U1-U3, own voltage Uw will be voltage connected to U1 terminals of X9 connector and reference voltage will be voltage connected to U3 terminals of connector X8.

So that impulse at chosen START-x input could start the switching process, following conditions should be met:

$$Uswd(.) \leq Uw \leq Uswg(.) \quad * \tag{3.89}$$

$$Usod(.) \leq Uo \leq Usog(.) \quad * \tag{3.90}$$

*Correct three-phase voltage Uw*** (3.91)

*Correct three-phase voltage Uo*** (3.92)

$$BLKZ = 0 \tag{3.93}$$

* Only in case, when War0 = 1 (table 3.3 #26)

**Only in case, when three-phase voltage control is enabled (table 3.3 #16,17,18,19)

where:

Uswd(.)	– lower boundary value of own voltage (residual) (table 3.1 #15);
Uswg(.)	– upper boundary value of own voltage (residual) (table 3.1 #16);
Usod(.)	– lower boundary value of reference voltage (residual) (table 3.1 #21);
Usog(.)	– upper boundary value of reference voltage (residual) (table 3.1 #22);
Uo	– measured value of reference voltage, phase 1;
Uw	– measured value of own voltage, phase 1;
BLKZ	– state of "external locking" digital input;
(.)	– depends on selected setting bank (Bank-1,...,Bank-4);

3.5.10.5.2. Closing of circuit breaker in GBN mode

If conditions 3.89, 3.90, 3.91, 3.92 i 3.93 are fulfilled synchronizer sends signal ZW closing the circuit breaker. If switching was successful and was confirmed by signals coming from circuit breaker, synchronizer passes to **standstill** after on (fig. 3.26). . In **standstill** after on state display presents current values of measured voltages **Uw** i **Uo**, (in % of rating value, in example voltage pair U1-U3 is shown), frequencies **fw** and **fo** and phase difference **dfi**.

```
SGBN  B1  G1  ODST_PP
U1=   5,7%  f1=------Hz
U3=   5,7%  f3=------Hz
dfi=----°
```

Fig. 3.26 Switching confirmation in SGBN mode

If there is lack of signals from auxiliary contacts of the breaker, confirming unequivocally closed state, synchronizer passes to **emergency standstill** state.

```
ODSTAWIENIE     1
U1=   5,7%  f1=------Hz
U3=   5,7%  f3=------Hz
faza  nieokreślona
```

Fig. 3.27 Unsuccessful switching

✶✶✶✶ arising in the last line indicate that measured angle is the real angle of phase shift between measured voltages connected to synchronizer inputs, (<u>without correction by constant phase shift</u>).

Irrespective of the reason of standstill, after about 2 seconds synchronizer comes back to stand-by status.

Settings fi1, … ,fi7 (table 3.3 #5,6,7,8,9,10,11) enable correction of constant phase shift, which is "seen" by synchronizer between measuring inputs. It is useful in situation, when as a result of phase shifts caused by measuring transformers or transformers phase difference at measuring terminals isn't equal to phase difference at both sides of circuit breaker. If such phase shifts don't exist, those settings should be set to 0.

If any od conditions 3.89 i 3.90 isn't fulfilled and setting War0 = 0 (table 3.3 #25) the synchronizer starts waiting for meeting these requirement (fig. 3.28) Maximal time of waiting for meeting conditions is determined by setting Tmax (table 3.1 #24).

```
U1:  2,5<   6,1%<  7,5
U3:  2,5<   8,7%<  7,5

 OCZEK.  NA  WARUNKI
```

Fig. 3.28. *Waiting for conditions in SGBN mode*

In the example (fig. 3.28) condition 3.90 isn't fulfilled.

If during time Tmax (table 3.1 #24) all conditions are not met, synchronizer will pass to standstill state (fig 3.29)

ODSTAWIENIE		20:	67
U1 =	6,1%	F1=------	Hz
U3 =	8,7%	F2=------	Hz
faza nieokreślona			

Fig. 3.29 *Unsuccessful synchronization*

Code of unsuccessful synchronization's reason along with optional details is shown in the upper right corner of the display.

Regardless of the shutdown cause the synchronizer goes back to the waiting time once the registration has been completed.

3.5.10.5.3. Interruption of the switching process in SGBN mode

The synchronizer will automatically go into **emergency shutdown status**, if during the switching status, at any time one of the conditions specified below has not been met:

$$Uo \leq Uog(.) \quad (3.94)$$

$$Uw \leq Uwg(.) \quad (3.95)$$

*Correct three-phase voltage Uw** (3.96)

*Correct three-phase voltage Uo** (3.97)

$$t < Tmax(.) \quad (3.98)$$

* Only in case, when three-phase voltage control is enabled (table 3.3 #16,17,18,19)

where:

Uwg(.)	– upper limit of own voltage (table 3.1 #12);
Uog(.)	– upper limit of reference voltage (table 3.1 #18);
Tmax(.)	– maximum time of switching process (table 3.1 #24);
t	– time that elapsed from the start of switching process;
Uw	– rms value of measured voltage Uw, phase 1;
Uo	– rms value of measured voltage Uo, phase 1;
(.)	– depends on selected setpoint bank (Bank-1,...,Bank-4);

The synchronizer may also automatically go into **emergency shutdown status**, if during the switching status, at any time, the status of any of the inputs has changed:

- W1o,W2o,...,W8o,
- W1z,W2z,...,W8z,
- BANK1, BANK2, BANK3, BANK4,
- WBRx,
- STOP.

Regardless of the shutdown cause the synchronizer goes back to the waiting time once the registration has been completed.

3.5.10.6. Switching without synchronism control – BKS mode

Under precisely defined circumstances the closing of circuit breakers may, and in fact – it has to be performed without synchronism control. Fig. 3.30 shows an example of such situation.

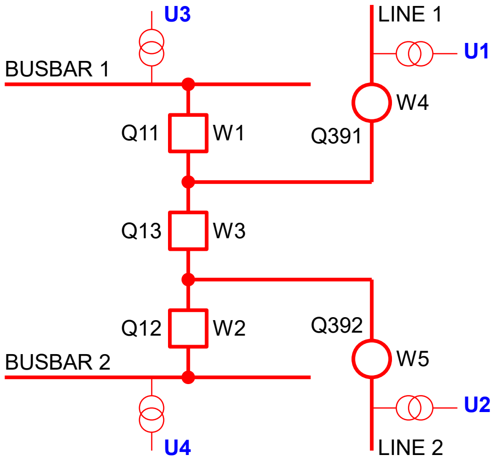

Fig. 3.30. Example of BKS switching

For instance: when closing Q13 circuit breaker under the circumstances shown in fig. 3.30 no voltage systems are switched. At the same time there is no information (no measurement of) about voltage on both sides of the Q13 circuit breaker.

A decision about BKS switching is taken by the synchronizer on the basis of comparison of current status of monitored circuit breakers and disconnectors with settings saved in the matrix with permissible statuses (3.5.4. Matrix of switching station states).

3.5.10.7. Error codes and reasons for non-switching

Shutdown reasons:

Code	Description
1:	No switching confirmation
5:	Frequency differential df > 15%
6:	Frequency differential df < -15%
8:	Rms value of voltage Uw < 65%
9:	Rms value of voltage Uo < 65%
14:	In the setpoints it is forbidden to switch from "the bottom” and "from the top”
17:	Supply voltage is too low
20:	Maximum permissible switching time has expired Tmax
22:	Change of status at synchronizer's binary inputs during switching
23:	Incorrect voltage U1 was detected (3.5.6. Three-phase voltage control)
24:	Fuses of measuring transformers have been activated
25:	Loss of WBR signal (if 3WBR = 0 table 3.3 #26)
26:	Wartość skuteczna napięcia Uw mniejsza od Uwd (table 3.1 #11)

Code	Description
27:	Wartość skuteczna napięcia Uw większa od Uwg (table 3.1 #12)
28:	Wartość skuteczna napięcia Uo mniejsza od Uod (table 3.1 #17)
29:	Wartość skuteczna napięcia Uo większa od Uog (table 3.1 #18)
30:	Wykryto niepoprawne napięcie U2 (3.5.6. Three-phase voltage control)
31:	Wykryto niepoprawne napięcie U3 (3.5.6. Three-phase voltage control)
32:	Wykryto niepoprawne napięcie U4 (3.5.6. Three-phase voltage control)
33:	Utrata połączenia z TS-20 (table 3.3 #27)
34:	Utrata sygnału WBR1 (jeżeli 3WBR = 1 table 3.3 #26)
35:	Utrata sygnału WBR2 (jeżeli 3WBR = 1 table 3.3 #26)
36:	Utrata sygnału WBR3 (jeżeli 3WBR = 1 table 3.3 #26)
37:	Wykryto niepoprawne napięcie szczątkowe U1 (3.5.6. Three-phase voltage control)
38:	Wykryto niepoprawne napięcie szczątkowe U2 (3.5.6. Three-phase voltage control)
39:	Wykryto niepoprawne napięcie szczątkowe U3 (3.5.6. Three-phase voltage control)
40:	Wykryto niepoprawne napięcie szczątkowe U4 (3.5.6. Three-phase voltage control)
41:	Zmiana trybu pracy (jeżeli Atrb = 0 table 3.3 #20)

Detailed of no conditions for switching:

Code	Description
32:	dU < dUd (table 3.1 #7)
33:	Uw < Uswd (table 3.1 #15)
35:	Uo < Usod (table 3.1 #21)
36:	Drift exceeded (table 3.1 #9)
37:	Fw < Fwd (table 3.1 #13)
39:	Fo < Fod (table 3.1 #19)
41:	Uw < Uwd (table 3.1 #11)
43:	Uo < Uod (table 3.1 #17)
52:	dfi < -dfi (table 3.1 #5)
64:	dU > dUg (table 3.1 #8)
65:	Uw > Uswg (table 3.1 #16)
67:	Uo > Usog (table 3.1 #22)
68:	Drift exceeded (table 3.1 #9)
69:	Fw > Fwg (table 3.1 #14)
71:	Fo > Fog (table 3.1 #20)
73:	Uw > Uwg (table 3.1 #12)
75:	Uo > Uog (table 3.1 #18)
84:	dfi > +dfi (table 3.1 #6)

96: dU unknown (unmeasurable)
97: Uw unknown (unmeasurable)
99: Uo unknown (unmeasurable)
100: Drift unknown (unmeasurable)
101: Fw unknown (unmeasurable)
103: Fo unknown (unmeasurable)
105: Uw unknown (unmeasurable)
107: Uo unknown (unmeasurable)
116: dfi unknown (unmeasurable)
131: dU outside the range (table 3.1 #1) i (table 3.1 #2)
132: df outside the range (table 3.1 #3) i (table 3.1 #4)
133: dfi outside the range (table 3.1 #23)

3.5.10.8. Viewing and modification of settings and measurement of some parameters of power network (TEST)

TEST mode enables:

1. Setting, viewing and changing parameters, introducing and changing an address for serial transmission.
2. Measurement of breaker switching time tw, when taking settings into consideration.
3. Measurement of angle fi of constant phase shift between measured signals Uw and Uo.
4. Measurement of set coefficient C in generator voltage control system.

To set TEST mode one should:

1.Remove signal from WBR input (if it was active)

2.Feed the voltage at TEST input or keep pressed by about 2 sec. key **MENU**.

Active state of WBR input **locks** (disables) setting TEST mode. WBR signal locks also possibility of settings modification via service connection or via USB port. If WBR signal arises **after** stetting TEST mode, it will be possible further viewing of settings, but possibility of their modification will be locked.

To leave TEST mode one should:

1. Remove voltage from TEST input if TEST mode was entered by setting a voltage at TEST input or::
2. Keep pressed during about 2 seconds key ESC in the first menu screen (fig. 3.31) if TEST mode was entered by keeping pressed MENU key.

After entering TEST mode main screen of TES mode is displayed (fig. 3.31)

```
TEST  →  settings
         measur.
```

Fig. 3.31

On the right side of the display there are procedure names:

1. **„settings”-** procedure used for viewing and modification of settings
2. **„measur.”-** procedure used for measurement of circuit breaker closing time, phase shift between measured voltages and setting value of C coefficient in in generator voltage control system.

3.5.10.8.1. Settings

Synchronizer is delivered by manufacturer with factory settings introduced. After installation of synchronizer these settings should be properly modified such, that they determine switching conditions foe a given object.

Settings are grouped in 4 setting banks: B1, B2, B3, B4. Listing of settings included in single bank is provided in table 3.1.

Supplementary 2 setting banks – G1, G2 – include settings connected with synchronizer cooperation with generator systems. Listing of settings included in single generator bank is provided in table 3.2.

Lack of selection of one (and only one) setting bank from the group B1, B2, B3 and B4 will cause disabling of synchronization. In case of lack of selection of generator bank (G1 or G2) bank G1 will be selected automatically.

Apart of six above mentioned groups of settings synchronizer requires introducing also supplementary settings – circuit breaker closing times and corrections for phase shifts between measured voltages. These settings are listed in table 3.3.

Columns: SYN, ZSK, SBN, GBN, SGBN, TEST determine, if a given setting is considered (if it has any influence on operation of the device) in selected mode of operation. “+” denotes that the setting is considered and “-” that it is not.

Table 3.1. Bank of switchable settings (one of four)

#	Symbol	Setpoint range	Resolution	Def	Setpoint name	SYN	ZSK	SBN	GBN	SGBN	TEST
1	-dU	(1 – 20)%Uw	1 %Uw	5%	Lower boundary value of voltage difference during generator synchronization	+	-	-	-	-	-
2	+dU	(1 – 20)%Uw	1 %Uw	5%	Upper boundary value of voltage difference during generator synchronization	+	-	-	-	-	-
3	-df	(0,1 – 3)%fw	0,01 %fw	1,00%	Permissible frequ78ency difference during switching the generator "from bottom"	+	-	-	-	-	-
4	+df	(0,1 – 3) %fw	0,01 %fw	1,00%	Permissible frequ78ency difference during switching the generator "from top"	+	-	-	-	-	-
5	-dfi	0 – 60 ° *	1°	30°	Lower phase difference of voltages switched by a given circuit breaker	-	+	-	-	-	-
6	+dfi	0 – 60 °	1°	30°	Upper phase difference of voltages switched by a given circuit breaker	-	+	-	-	-	-

#	Symbol	Setpoint range	Resolution	Def	Setpoint name	SYN	ZSK	SBN	GBN	SGBN	TEST
7	dUd	(1 – 20)%Uw	1 %Uw	5%	Lower value of voltage difference switched by a given circuit breaker	-	+	-	-	-	-
8	dUg	(1 – 20)%Uw	1 %Uw	5%	Upper value of voltage difference switched by a given circuit breaker	-	+	-	-	-	-
9	dr	(0,1 – 20) °/s	0,1 °/s	1,0 °/s	Permissible drift of phase difference during switching by a given circuit breaker	-	+	-	-	-	-
10	Tg	(1 – 10) s	1 s	5s	Boundary time for phase drift measurements during switching by a given circuit breaker	-	+	-	-	-	-
11	Uwd	(65–100) %Un	1 % Un	90%	Lower boundary value of own voltage	+	+	-	+	-	+
12	Uwg	(100–120) %Un	1 %Un	110%	Upper boundary value of own voltage	+	+	-	+	-	+
13	fwd	(90–100)%fn	1 %fn	95%	Lower boundary value of own voltage frequency	-	-	-	+	-	+
14	fwg	(100–110)%fn	1 %fn	105%	Upper boundary value of own voltage frequency	-	-	-	+	-	+
15	Uswd	(0 – 5) %Un	0,1 %Un	2,5%	Lower boundary value of residual own voltage	-	-	+	-	+	+
16	Uswg	(0 – 30) %Un	0,1 %Un	10,0%	Upper boundary value of residual own voltage	-	-	+	-	+	+
17	Uod	(65–100)%Un	1 %Un	90%	Lower boundary value of reference voltage	+	+	+	-	-	+
18	Uog	(100–120) %Un	1 %Un	110%	Upper boundary value of reference voltage	+	+	+	-	-	+
19	fod	(90–100)%fn	1 %fn	95%	Lower boundary value of reference voltage frequency	-	-	+	-	-	+
20	fog	(100–110)%fn	1 %fn	105%	Upper boundary value of reference voltage frequency	-	-	+	-	-	+
21	Usod	(0 – 5) %Un	0,1 %Un	2,5%	Lower boundary value of residual reference voltage	-	-	-	+	+	+
22	Usog	(0 – 30) %Un	0,1 %Un	10,0%	Upper boundary value of residual reference voltage	-	-	-	+	+	+
23	fia	(2-20)°	1°	2°	Permissible angular deviation	+	-	-	-	-	-
24	Tmax	(0-1800)s	10s	60s	Maximal duration of switching process for a given circuit breaker	+	+	-	-	-	-
25	Lp	1 – 100	1	1	Number of repetitions for signal turning on a circuit breaker	+	-	-	-	-	-

Table 3.2. Switchable setting banks for generator (one of two)

#	Symbol	Setpoint range	Resolution	Def	Setpoint name	SYN	ZSK	SBN	GBN	SGBN	TEST
1	ww	0,1 – 1	0,1	0,5	Pulse duty factor for pulses adjusting generator voltage	+	-	-	-	-	-
2	dfu	(0,2 – 10)%Fs	0,1 %Fs	2,0%	Difference of frequencies from which starts adjustment of generator voltage	+	-	-	-	-	-
3	TrF	(0,02 – 1) s	0,01 s	0,10s	Duration time for single pulse adjusting generator rotational speed	+	-	-	-	-	-
4	C	0 – 2	0,1 %/%	0 %/%	Coefficient of generator voltage characteristic curve	+	-	-	-	-	-
5	ZL-	T/N	–	1	Enabling for generator switching "from bottom"	+	-	-	-	-	-
6	ZL+	T/N	–	1	Enabling for generator switching "from top"	+	-	-	-	-	-

Table 3.3. Supplementary settings (unswitchable)

#	Symbol	Setpoint range	Resolution	Def	Setpoint name	SYN	ZSK	SBN	GBN	SGBN	TEST
1	tw1	(1 – 320) ms	1 ms	100 ms	Lead time for circuit breaker W1	+	-	-	-	-	-
2	tw2	(1 – 320) ms	1 ms	100 ms	Lead time for circuit breaker W2	+	-	-	-	-	-
3	tw3	(1 – 320) ms	1 ms	100 ms	Lead time for circuit breaker W3	+	-	-	-	-	-
4	tw4	(1 – 320) ms	1 ms	100 ms	Lead time for circuit breaker W4 *	+	-	-	-	-	-
5	fi1	-90° – +90°	0,1 °	0 °	Adjustment of the U1-U2 voltage phase shift	+	+	+	+	+	-
6	fi2	-90° – +90°	0,1 °	0 °	Adjustment of the U1-U3 voltage phase shift	+	+	+	+	+	-
7	fi3	-90° – +90°	0,1 °	0 °	Adjustment of the U1-U4 voltage phase shift	+	+	+	+	+	-
8	fi4	-90° – +90°	0,1 °	0 °	Adjustment of the U2-U1 voltage phase shift	+	+	+	+	+	-
9	f5	-90° – +90°	0,1 °	0 °	Adjustment of the U2-U3 voltage phase shift	+	+	+	+	+	-
10	fi6	-90° – +90°	0,1 °	0 °	Adjustment of the U2-U4 voltage phase shift	+	+	+	+	+	-
11	fi7	-90° – +90°	0,1 °	0 °	Adjustment of the U3-U4 voltage phase shift	+	+	+	+	+	-
12	U1ok	T/N	–	0	Active U1 input status_ok	+	+	+	+	+	-

#	Symbol	Setpoint range	Resolution	Def	Setpoint name	SYN	ZSK	SBN	GBN	SGBN	TEST
13	U2ok	T/N	–	0	Active U2 input status_ok	+	+	+	+	+	-
14	U3ok	T/N	–	0	Active U3 input status_ok	+	+	+	+	+	-
15	U4ok	T/N	–	0	Active U4 input status_ok	+	+	+	+	+	-
16	U1-3f	T/N	–	1	3-phase control of U1 voltage	+	+	+	+	+	-
17	U2-3f	T/N	–	1	3-phase control of U2 voltage	+	+	+	+	+	-
18	U3-3f	T/N	–	1	3-phase control of U3 voltage	+	+	+	+	+	-
19	U4-3f	T/N	–	1	3-phase control of U4 voltage	+	+	+	+	+	-
20	Atrb	T/N	–	1	Automatic selection of operational mode	+	+	+	+	+	+
21	Bimp	T/N	–	0	Pulse selection of setpoint bank	+	+	+	+	+	+
22	Reg	T/N	–	0	Voltage and rotation control on	+	-	-	-	-	-
23	Bout	T/N	–	0	Contact information about selected setpoint bank (only when “Reg” is off)	+	+	+	+	+	+
24	WarU	T/N	–	1	SYN and ZSK criteria have to be met before START signal is supplied	+	+	+	+	+	-
25	War0	T/N	–	1	SBN, GBN and SGBN criteria have to be met before START signal is supplied	+	+	+	+	+	-
26	3WBR	T/N	–	0	Individual WBR inputs for W1,W2,W3	+	+	+	+	+	+
27	TS20	T/N	–	0	TS-20 presence control	+	+	+	+	+	-
28	Twyl	(0,1 – 2)s	0,1s	1s	Permissible time of transient status of circuit breaker	+	+	+	+	+	-
29	Todl	(0,1 – 20)s	0,1s	10s	Permissible time of transient status of disconnector	+	+	+	+	+	-
30	Kom	T/N	–	0	Operational mode with switching	+	+	+	+	+	-

* niewykorzystywane w SS-07-3D

Viewing and modification of settings is performed via procedure of „setting” by means of keys located on synoptic plate. Reading of settings is also possible via serial service links RS1 or RS4 and USB port on the front panel.

For viewing or modification of settings, after appearance on LCD the message as in fig. 3.31 using buttons **<** and **>,** one should locate an arrow (→) at text string "settings" and then press button **MENU.** After appearance the screen as in fig. 3.32 locate an arrow at text string "settings" and once more press button **MENU**.

```
TEST  →  setting
```

Fig. 3.32

A "page" will appear on the display (as e.g. in fig. 3.33) containing in its first column item number from the table of settings, in second column symbol of parameter and in the third column the set value of this parameter. Four settings are displayed on each "page".

```
1  →  tw1  =  100ms
2     tw2  =  110ms
3     tw3  =  120ms
4     tw4  =  130ms
```

Fig. 3.33

Settings can be scrolled by means of buttons **< >**. One can exit settings pushing button **ESC**.

Settings included in switchable banks (table 3.1 and 3.2) are numbered according to numbers of banks they are included in. For example setting -dU from bank 1 is denoted by abbreviation -dU1, setting -dU from bank 2 is abbreviated as -dU2 etc.

To change any setting one should:

1. Place arrow (→) at row containing the setting to be changed,
2. Press button **MENU**. Symbol **„ = ”** in setting display will change to „ ***** ”,
3. To increase value of setting press **>** and to decrease it press **<** ,
4. Press **MEM** button to store changed setting value in the register. Confirmation of the storage operation id change of „ ***** ” to symbol „ **=** ”.

After performing all changes in settings press **MEM** button once again. Synchronizer will inform that changes have been stored in the register and asks if they should be stored in non-volatile memory (fig. 3.34).

```
STORE  CHANGES?
MEM  - store
ESC  - ignore  changes
MENU- return  to  set.
```

Fig. 3.34

Pressing **MEM** button stores changed setting values in the memory and displays message acknowledging of storage operation (fig. 3.35), and pressing **ESC** button causes escaping setting section without storage of introduced changes. Pressing **MENU** button causes return to viewing/modification of settings.

```
       CHANGES
  HAVE  BEEN  STORED

      press  ESC
```

Fig. 3.35

3.5.10.8.2. Measurement of time tw

After entering TEST mode main screen of TEST mode is displayed (fig. 3.36).

```
TEST  →  settings
         measur.


```

Fig. 3.36

Using buttons **< >**, place arrow (→) at **"measur."** function and press button **MENU**. Available functions will appear on the display (fig. 3.37)

```
TEST  → time tw
        ang fi
        ident.generat
```

Fig. 3.37

Synchronizer SS-07 in TEST mode measures closing time of circuit breaker by means of indirect method, measuring time between closing of relay contacts at synchronizer output ZWx and closing of auxiliary contacts of circuit breaker Wxz, where x – number of selected circuit breaker.

After appearance on LCD state as like in fig. 3.37, using buttons **< >**, place arrow (→) at function „time tw" and press **MENU** button, than time measurement procedure will appear (fig. 3.38).

```
MEASUR.  TIME  tw1
met.auxil .contacts.
send  signal:
START or  (MENU+ESC)
```

Fig. 3.38

Using buttons **< >**, one can select circuit breaker BR1, BR2 or BR3 and corresponding time tw1, tw2 or tw3.

If conditions for switching in mode **SBN, GBN** or **SGBN** are met and breaker is unequivocally open, external signal **START-X** or equivalent signal START from synoptic plate (send by pressing and keeping of button **MENU,** and then pressing **ESC**) will cause generation of pulse **ZW-X** (of duration max. 620ms) turning on the breaker and starting time counter for measurement of breaker closing time „tw". Starting the counter takes place in the moment of closing relay contacts on synchronizer output ZW. Counter stops in the moment of voltage arising at Wxz input, irrespective of state of Wxo input, where x – number of selected breaker.

Display presents result of closing time measurement as in example shown in fig. 3.39 for circuit breaker BR1.

If 640ms passes from moment of closing relay contacts at ZW output and state of auxiliary contacts doesn't change or is ambiguous, synchronizer will pass to **emergency standstill**, and an error message will appear on the display. The same change of state will be performed if in the moment of activation of circuit breaker closing voltage condition will not be met for any potential-free mode.

```
MEASUR tw1= 102.3ms

ESC-return
```

Fig. 3.39

Pressing **ESC** will cause return to the state shown in fig. 3.37.

3.5.10.8.3. Measurement of angle fi

Procedure „angle fi" enables measurement and **compensation of constant phase shift angle** (denoted as „fi”), between measured voltages Uw and Uo.

$$fi = fi(Uo) - fi(Uw) \tag{3.99}$$

Constant phase shift angle is due to phase shifts at transformers and measuring transformers. Synchronizer enables measurement and compensation of this angle in the range ± 90°.

After entering TEST mode main screen of TEST mode is displayed (fig.3.40).

```
TEST  → settings
        measur.
```

Fig. 3.40

Using buttons **< >**, place arrow (→) at **"measur."** function and press button **MENU**. Available functions will appear on the display (fig. 3.41)

```
TEST    time tw
      → angle fi
        ident.generat
```

Fig. 3.41

After on the display appears state as shown in fig. 3.41, using buttons **< >**, place an arrow (→) at function „angle fi” and press button **MENU**. Result of measurement will be presented on the display as in example shown in fig. 3.42.

```
   fi1 = 12.35
 Przesunięcie fazy
 pomiędzy wejściami
     U1 i U2
```

Fig. 3.42

Using buttons **< >**, one can switch between voltage pairs selected for measurement.

One should remember measured sign and value of constant phase shift angle between measured and introduce them into settings (table 3.3 #5,6,7,8,9,10,11).

Exit from "angle fi" procedure is performed by pressing button **ESC**.

3.5.10.8.4. Measurement of coefficient C

This procedure id used for measurement of slope coefficient of generator voltage characteristic curve as a function of its rotational speed (parameter „C” in settings, table 3.2 #4). Synchronizer SS-07-3D can equalize voltages of synchronized objects taking into account this characteristic.

After entering TEST mode main screen of TEST mode is displayed (fig. 3.43).

```
TEST  →  settings
         measur.
```

Fig. 3.43

Using buttons **< >**, place arrow (→) at **"measur."** function and press button **MENU**. Available functions will appear on the display (fig. 3.44)

```
TEST     time tw
         ang fi
      →  ident.generat
```

Fig. 3.44

When information as in fig. 3.45 is displayed, one should manually set initial frequency of generator voltage. Actual values of frequency Fg and generator voltage Ug are displayed in first row of LCD.

```
Fg=47.62Hz  Ug= 98.1%
Set initial
frequency of GEN
MENU-cont.  ESC-ret.
```

Fig. 3.45

Pressing **MENU** button will cause saving initial frequency Fg and initial voltage Ug of the generator and displaying the message as in fig. 3.46.

After manual setting of final frequency and pressing **MENU**, results of "C" parameter measurement will be displayed as in example shown in fig. 3.47.

```
Fg=47.62Hz  Ug= 98.1%
Set the end value
frequency ... GEN
MENU-cont.  ESC-ret.
```

Fig. 3.46

```
Fp=47.50   Fk=52.50Hz
Up=102.1   Uk=102.1%
     C =    0.0 %/ %
ESC-return
```

Fig. 3.47

Fp, Up – measured initial values,

Fk, Uk – measured final values.

Return to the beginning of **TEST** mode can be achieved by pressing **ESC** button several times.

4. Technical data

Table 4.1. Characteristics of measuring inputs

Rating voltage Un	100/√3 or 100 V RMS
Absorbed power at rating voltage per one input	< 0.5 VA
Measuring range for rms voltage	0…1.3 Un
Maximal permissible continuous voltage	2 Un
Sampling frequency	8 kHz

Table 4.2. Characteristics of binary inputs

Rating voltage	220 V DC
Absorbed power at rating voltage per one input	< 0.2 W
Typical switching voltage (threshold)	155…170 V DC
Maximal permissible continuous voltage (any polarization)	300 V DC
Sampling frequency	0.4 kHz

Table 4.3. Characteristics of power supply input

Rating voltage	220VDC
Minimal voltage required for correct operation	154VDC
Absorbed power at rating voltage	<15W
Maximal permissible continuous voltage	300VDC

Table 4.4. Characteristics of rely outputs ZW1,ZW2,ZW3,OG,OD,NG,ND,UW,SS

Rely type	Relpol RM83P
Maximal permissible continuous current	1A
Absorbed power at maximal permissible continuous current	<0.14W
Maximal permissible 10-second current	4A
Other parameters	As for Relpol RM83P

Table 4.5. Characteristics of rely outputs BL, GP

Rely type	Relpol RM96
Maximal permissible continuous current	1A
Absorbed power at maximal permissible continuous current	<0.14W
Maximal permissible 10-second current	4A
Other parameters	As for Relpol RM96

*Table 4.6. Zaciski SS-07-*3D

#	Terminal name	Symbol	Connector
Input terminals for voltage U1 measurement			
1	Measured voltage U1, phase 1	U1r-1	X9-5
2	Measured voltage U1, phase 1	U1r-2	X9-6
3	Measured voltage U1, phase 2	U1s-1	X9-7
4	Measured voltage U1, phase 2	U1s-2	X9-8
5	Measured voltage U1, phase 3	U1t-1	X9-9
6	Measured voltage U1, phase 3	U1t-2	X9-10
Input terminals for voltage U2 measurement			
7	Measured voltage U2, phase 1	U2r-1	X9-11
8	Measured voltage U2, phase 1	U2r-2	X9-12
9	Measured voltage U2, phase 2	U2s-1	X9-13
10	Measured voltage U2, phase 2	U2s-2	X9-14
11	Measured voltage U2, phase 3	U2t-1	X9-15
12	Measured voltage U2, phase 3	U2t-2	X9-16
Input terminals for voltage U3 measurement			
13	Measured voltage U3, phase 1	U3r-1	X8-5
14	Measured voltage U3, phase 1	U3r-2	X8-6
15	Measured voltage U3, phase 2	U3s-1	X8-7
16	Measured voltage U3, phase 2	U3s-2	X8-8
17	Measured voltage U3, phase 3	U3t-1	X8-9
18	Measured voltage U3, phase 3	U3t-2	X8-10
Input terminals for voltage U4 measurement			
19	Measured voltage U4, phase 1	U4r-1	X8-11
20	Measured voltage U4, phase 1	U4r-2	X8-12
21	Measured voltage U4, phase 2	U4s-1	X8-13
22	Measured voltage U4, phase 2	U4s-2	X8-14
23	Measured voltage U4, phase 3	U4t-1	X8-15
24	Measured voltage U4, phase 3	U4t-2	X8-16
Input terminals for selection of operation mode digital signals and power supply inputs			
25	Mode selection - SYN	SYN	X10-3
26	Mode selection - ZSK	ZSK	X10-4
27	Mode selection - SBN	SBN	X10-5
28	Mode selection - GBN	GBN	X10-6
29	Mode selection - SGBN	SGBN	X10-7

#	Terminal name	Symbol	Connector
30	Mode selection - TEST	TEST	X10-8
31	Selection of Generator 2	GEN 2	X10-9
32	Selection of Generator 1	GEN 1	X10-10
33	Optional (-) of operation mode selection	TRB-C	X10-13
34	Auxiliary voltage for operation mode switch	Up	X10-14
35	Power supply Uv (+)	V+	X10-15
36	Power supply Uv (-)	V-	X10-16
Input terminals for selection of setting bank and measurement reliability			
37	Selection of setting bank No. 1 (-)	BN1-C	X1-1
38	Selection of setting bank No. 1 (+)	BN1	X1-2
39	Selection of setting bank No. 2 (-)	BN2-C	X1-3
40	Selection of setting bank No. 2 (+)	BN2	X1-4
41	Selection of setting bank No. 3 (-)	BN3-C	X1-5
42	Selection of setting bank No. 3 (+)	BN3	X1-6
43	Selection of setting bank No. 4 (-)	BN4-C	X1-7
44	Selection of setting bank No. 4 (+)	BN4	X1-8
45	Measurement of voltage U1 – reliability information (-)	U1ok -C	X1-9
46	Measurement of voltage U1 – reliability information (+)	U1ok	X1-10
47	Measurement of voltage U2 – reliability information (-)	U2ok -C	X1-11
48	Measurement of voltage U2 – reliability information (+)	U2ok	X1-12
49	Measurement of voltage U3 – reliability information (-)	U3ok -C	X1-13
50	Measurement of voltage U3 – reliability information (+)	U3ok	X1-14
51	Measurement of voltage U4 – reliability information (-)	U4ok -C	X1-15
52	Measurement of voltage U4 – reliability information (+)	U4ok	X1-16
Input terminals for control signals			
53	Synchronization start for circuit breaker 1 (-)	START1-C	X2-1
54	Synchronization start for circuit breaker 1 (+)	START1	X2-2
55	Synchronization start for circuit breaker 2 (-)	START2-C	X2-3
56	Synchronization start for circuit breaker 2 (+)	START2	X2-4
57	Synchronization start for circuit breaker 3 (-)	START3-C	X2-5
58	Synchronization start for circuit breaker 3 (+)	START3	X2-6
59	Stop (interrupt) of synchronization process (-)	STOP-C	X2-11
60	Stop (interrupt) of synchronization process (+)	STOP	X2-12
61	External locking of circuit breaker closing (-)	BLKZ-C	X2-13
62	External locking of circuit breaker closing (+)	BLKZ	X2-14

#	Terminal name	Symbol	Connector
63	Signal selecting synchronizer to operate (or W1 operation enabled) (-)	WBR1-C	X2-15
64	Signal selecting synchronizer to operate (or W1 operation enabled) (+)	WBR1	X2-16
65	W2 operation enabled (-)	WBR2-C	X2-9
66	W2 operation enabled (+)	WBR2	X2-10
67	W3 operation enabled (-)	WBR3-C	X2-7
68	W3 operation enabled (+)	WBR3	X2-8
Input terminals for status monitoring of circuit breaker W1			
69	Signal of circuit breaker W1 open	W1o	X3-13
70	Signal of circuit breaker W1 closed	W1z	X3-12
71	(-) for digital inputs of circuit breaker W1 status	-W1	X3-11
Input terminals for status monitoring of circuit breaker W2			
72	Signal of circuit breaker W2 open	W2o	X3-16
73	Signal of circuit breaker W2 closed	W2z	X3-14
74	(-) for digital inputs of circuit breaker W2 status	-W2	X3-15
Input terminals for status monitoring of circuit breaker W3			
75	Signal of circuit breaker W3 open	W3o	X4-13
76	Signal of circuit breaker W3 closed	W3z	X4-12
77	(-) for digital inputs of circuit breaker W3 status	-W3	X4-11
Input terminals for status monitoring of circuit breaker W4			
78	Signal of circuit breaker W4 open	W4o	X4-16
79	Signal of circuit breaker W4 closed	W4z	X4-14
80	(-) for digital inputs of circuit breaker W4 status	-W4	X4-15
Input terminals for status monitoring of circuit breaker W5			
81	Signal of circuit breaker W5 open	W5o	X5-13
82	Signal of circuit breaker W5 closed	W5z	X5-12
83	(-) for digital inputs of circuit breaker W5 status	-W5	X5-11
Input terminals for status monitoring of circuit breaker W6			
84	Signal of circuit breaker W6 open	W6o	X5-16
85	Signal of circuit breaker W6 closed	W6z	X5-14
86	(-) for digital inputs of circuit breaker W6 status	-W6	X5-15
Input terminals for status monitoring of circuit breaker W7			
87	Signal of circuit breaker W7 open	W7o	X3-10
88	Signal of circuit breaker W7 closed	W7z	X3-3
89	(-) for digital inputs of circuit breaker W7 status	-W7	X3-9
Input terminals for status monitoring of circuit breaker W8			

#	Terminal name	Symbol	Connector
90	Signal of circuit breaker W8 open	W8o	X4-10
91	Signal of circuit breaker W8 closed	W8z	X4-3
92	(-) for digital inputs of circuit breaker W8 status	-W8	X4-9
	Relay output terminals for closing circuit breaker		
93	Relay contact for closing circuit breaker W1	ZW1-C	X3-7
94	Relay contact for closing circuit breaker W1	ZW1	X3-8
95	Relay contact for closing circuit breaker W2	ZW2-C	X4-7
96	Relay contact for closing circuit breaker W2	ZW2	X4-8
97	Relay contact for closing circuit breaker W3	ZW3-C	X5-7
98	Relay contact for closing circuit breaker W3	ZW3	X5-8
	Signalling relay output terminals		
99	Contact of error signalling rely (synchronizer interlocking)	BL-C	X3-1
100	Contact of error signalling rely (synchronizer interlocking)	BL	X3-2
101	Rely contact for signalling correct synchronizer power supply / (Live contact) / watchdog	GP-C	X5-1
102	Rely contact for signalling correct synchronizer power supply /(Live contact) / watchdog	GP	X5-2
103	Relay contact signalling start of synchronization	SS-C	X5-3
104	Relay contact signalling start of synchronization	SS	X5-4
105	Relay contact signalling internal error	UW-C	X5-5
106	Relay contact signalling internal error	UW	X5-6
	Relay output terminals for rotation speed adjustment		
107	(+) supply voltage of rotational speed controller	RO-C	X3-6
108	Signal decreasing of rotational speed	OD	X3-5
109	Signal increasing of rotational speed	OG	X3-4
	Relay output terminals for voltage adjustment		
110	(+) supply voltage of voltage controller	RN-C	X4-6
111	Signal decreasing of voltage	ND	X4-5
112	Signal increasing of voltage	NG	X4-4
	Terminals of RS connector – communication channel 1		
	Optical version		
113	Transmitter line	RS1-TX	RS1-TX
114	Receiver line	RS1-RX	RS1-RX
	Terminals of RS connector – communication channel 2		
	Optical version		
115	Transmitter line	RS2-TX	RS2-TX
116	Receiver line	RS2-RX	RS2-RX

#	Terminal name	Symbol	Connector
Terminals of RS connector – communication channel 3			
Optical version			
117	Transmitter line	RS3-TX	RS3-TX
118	Receiver line	RS3-RX	RS3-RX
Terminals of RS connector – communication channel 4			
Optical version			
119	Transmitter line	RS4-TX	RS4-TX
120	Receiver line	RS4-RX	RS4-RX
USB – kanał komunikacyjny 4a			
USB na front panel			
121	USB connector (automatically disconnecting RS4 port in the moment of connecting any other device to USB port)	USB	USB
Ethernet, IEC-61850 – communication channel 5			
122	RJ45 Connector	ETH1	ETH1
Ethernet – communication channel 6			
123	RJ45 Connector	ETH2	ETH2

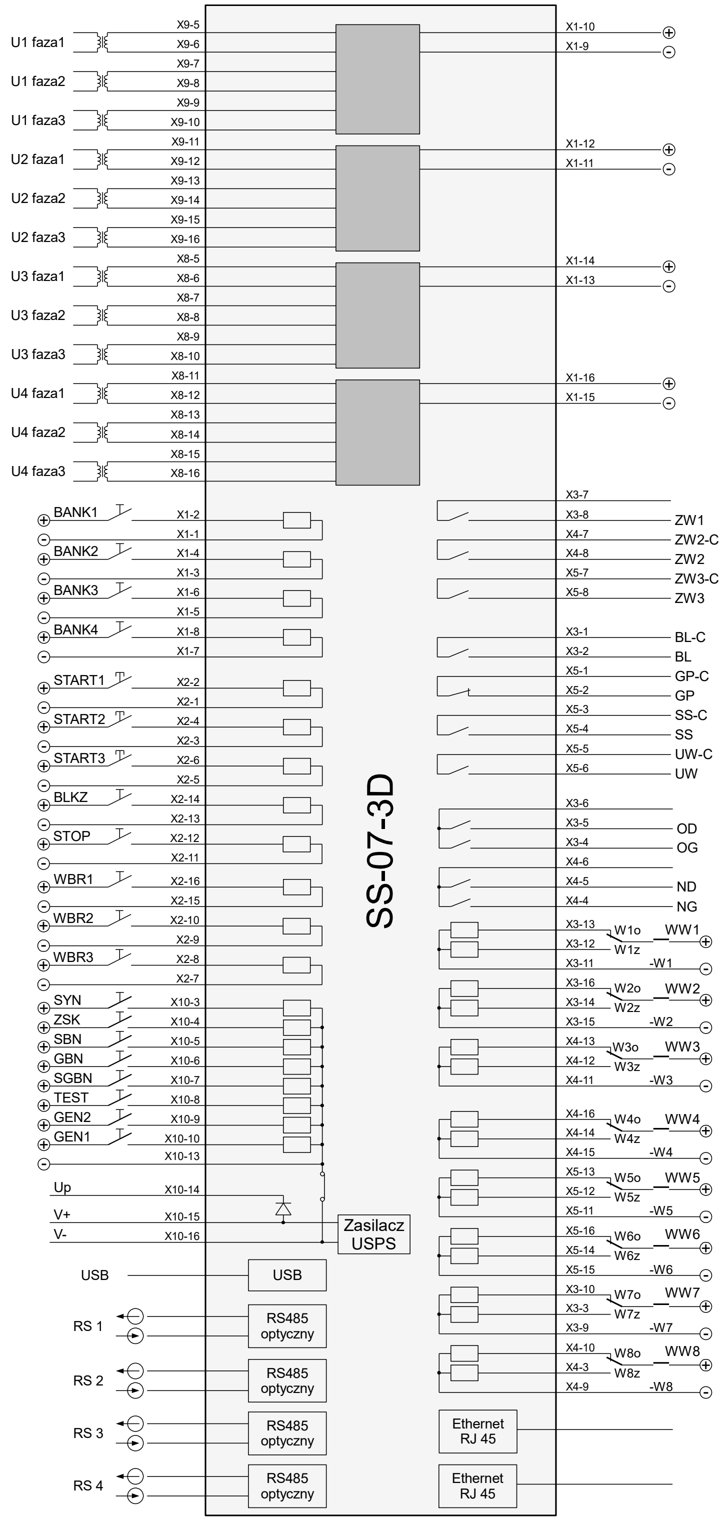

Fig. 4.1. Application diagram of synchronizer SS-07-3D

5. Data on complete delivery

Complete delivery for consumer includes:

- Synchronizer SS-07-3D
- Set of plug connectors
- Synchronizer SS-07-3D operating manual
- Guarantee certificate

6. Installation and commissioning

Installation of synchronizer should be performed according to widely accepted principles concerning protective devices, automation and control. During installation one should check conformity of automation system design with synchronizer documentation and its rating plate, paying particular attention to:

rating value of power supply voltage and its polarity,

rating measured voltage,

correctness of applied protective means for voltage circuits (ratings of fuses or rating currents and characteristics of tripping units),

current-carrying capacities of rely outputs,

correctness of assembly,

continuity of protective conductor,

modification of synchronizer settings proper for a given object.

Before first turning on device should stay for at least two hours in the room where it is to be installed for temperature levelling and moistness prevention.

Commissioning should be finished by performing functional tests of the device and, if needed, adjustment of settings.

7. Monitoring of synchronization process

7.1. Communication ports

Table 7.1. Specification of synchronizer SS-07-3D communication ports

Item	Type	Connector	Protocol	Functionality (default purpose)	Remarks
1	RS	RS1 (ST)	Modbus RTU	- Configuration of the device (settings) - Registration drawing - Making available current measurements, states of inputs, device status etc. - Fast link for visualization *	Functionality can be limited
2	RS	RS2 (ST)	IEC 60870-5-103	- Making available current measurements, states of inputs, device status etc.	Optional link
3	RS	RS3 (ST)	IEC 60870-5-103	- Making available current measurements, states of inputs, device status etc.	Optional link

Item	Type	Connector	Protocol	Functionality (default purpose)	Remarks
4	RS	RS4 (rear side) plus USB (front side)	Modbus RTU	- Configuration of the device (settings) - Registration drawing - Making available current measurements, states of inputs, device status etc. - Fast link for visualization *	Functionality can be limited
5	Ethernet	ETH1** (RJ45)	IEC 61850 and own protocol***	- Making available current measurements, states of inputs, device status etc. (IEC 61850)**** - Fast link for visualization *	
6	Ethernet	ETH2** (RJ45)	own protocol***	- Fast link for visualization *	Optional link

* Used for "real time visualization"
** Possible conversion to optical fibre link by means of external converter
*** Based on UDP, used for "fast visualization", can replace RS based links for visualization
**** Option

RS4 link can be used for connection of TS-20 synoptic plate.

Connecting PC computer to USB connector at front plate of SS-07-3D deactivates RS4 at rear panel of the device. After removing plug of USB cable port RS4 will be activated again.

7.2. Synoptic plate TS-20

Synchronization plate TS-20 (fig. 7.1) is intended for monitoring of synchronization process at operator's stand in control room. TS-20 – a device intended for installation in control desk in control room, in back-up panels or in place of synoptic plate in housing of synchronizer SS-07-3D and is connected directly to synchronizer by means of optical fibre or twisted pair.

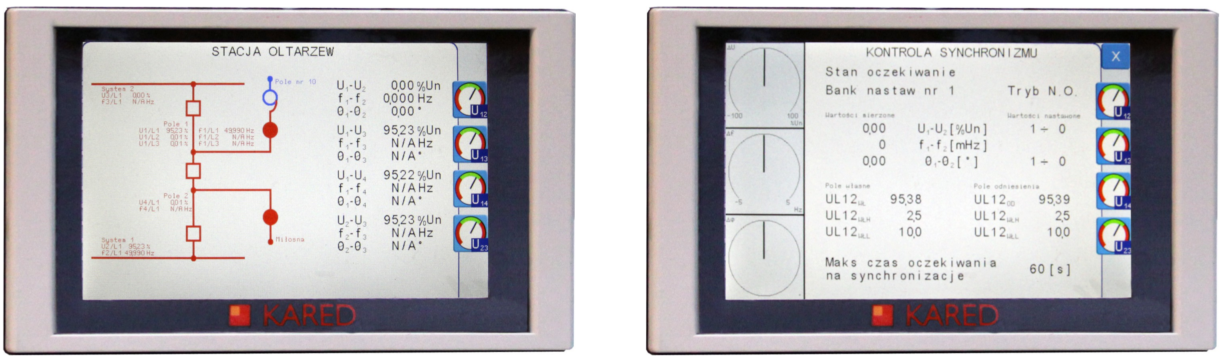

Fig. 7.1. Examples of screens of TS-20 synoptic plate

7.3. Visualization of synchronization process

Software iKar SYNVIEW enables local and remote visualization of synchronization process on so called "Virtual synchronization column" working on-line thanks to fast communication links (Fast Ethernet) on monitor of PC computer.

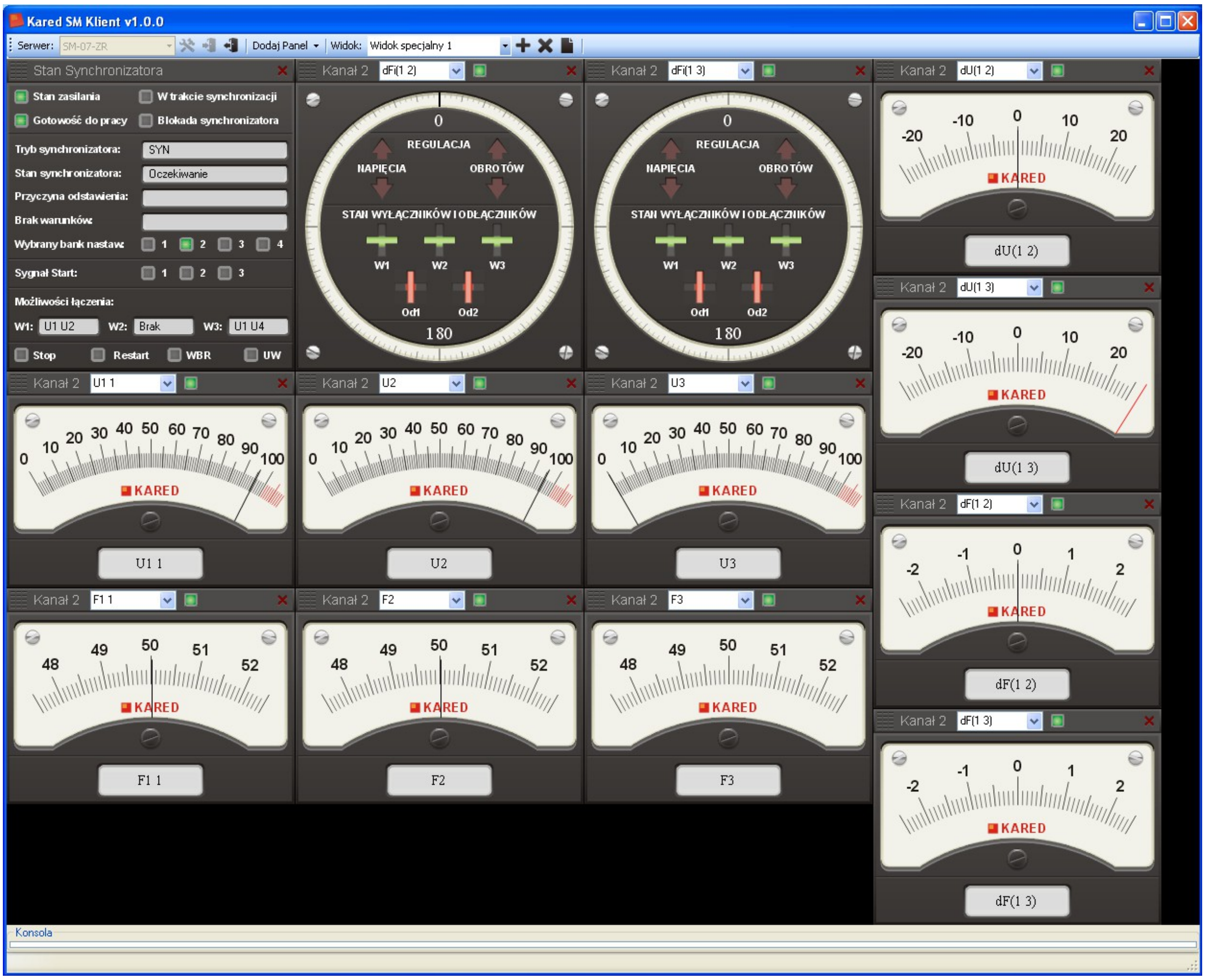

Fig. 7.2. Example screen of iKar SYNVIEW software

7.4. Communication with higher order system

Communication with higher order system via SS-07-3D synchronizer's communication links has been described in a separate document.

7.5. Event log

All changes of digital signals in synchronizer are stored in event log. These signals are:

at input X1: BANK1
BANK2
BANK3
BANK4

at input X2: START1
START2

	START3
	BLKZ
	WBR-1
	WBR-2
	WBR-3
at input X3:	status of circuit breaker W1
	status of circuit breaker W2
	status of circuit breaker W7
at input X4:	status of circuit breaker W3
	status of circuit breaker W4
	status of circuit breaker W8
at input X5:	status of circuit breaker W5
	status of circuit breaker W6
at input X10:	GEN1
	GEN2
	SYN
	ZSK
	SBN
	GBN
	SGBN
	TEST

Moreover, following events are stored:

- synchronizer turning on
- connection to USB
- disconnection of USB
- settings change via software
- settings change via keyboard
- change of operation status: stand-by, synchronization, drift measurement, standstill after on, emergency standstill,
- changes of signals U1_OK, U2_OK, U3_OK, U4_OK

Not used signals can be stored when they appear at the input, although their appearance is ignored by synchronizer.

Event log is serviced by iKar-SYN software. It enables, among others, uploading of stored events and their presentation on PC monitor.

7.6. Recorder of synchronization process

Synchronizer is provided with recorder storing events and rms values of measured quantities.

Following parameters are registered:

- status changes of digital inputs,
- status changes of circuit breakers,
- status changes of rely contacts,
- changes of internal status (operational status, information on successful switching, information on appearing errors,
- measured rms values of voltages at both sides of circuit breaker,
- measured values of frequencies of voltages at both sides of circuit breaker,
- results of measurements of differences of: voltage, frequency, phase.

Each event or result of measurement is provided with individual time stamp. Registration is triggered at the moment of start of synchronization process and ends some time after detecting of successful switching or passing the synchronizer to standstill state as a result of error.

Depending on duration of synchronization process, it is possible to register up to 64 runs of synchronization.

Recorder of synchronization process is serviced by iKar-SYN software. It enables, among others, uploading of registered synchronization runs, their visualization and performing analysis of synchronization process.

8. Operation

Synchronizers SS-07-3D manufactured by PUP KARED Sp. z o.o. are designed in such way, that they don't need any special service activities preformed by operator.

8.1. Routine tests

It is recommended to perform product test before end of guarantee period. It is recommended to use special tester enabling to test synchronizer in dynamic states, e.g. Power Unit Simulator. Test results are a base for possible prolonging the guarantee for the next period..

8.2. Detection and clearing of faults

In case of detection any irregularities in operation of the device contact manufacturer's representative, who will recommend further procedure.

When reporting a fault you should provide:

- type of synchronizer,
- serial number,
- place of installation,
- symptoms of fault,

- name of person conducting a case,
- e-mail and phone number for contacts.

9. Transportation and storage

Transport packaging should have the same impact and vibration strengths as determined in standards PN-EN 60255-21-1:1999 i PN-EN 6025-21-2:2000 for caution class 1.

Device delivered by manufacturer should be carefully unpacked without using excessive force or improper tools. After unpacking one should check visually, if the device hasn't any traces of external damages.

Device should be stored in clean, dry room in storage temperature included in the range from

-25°C to +70°C.

Relative humidity should be included in the range preventing condensation or frosting.

10. Disposal

If as a result of damage or completing the use of the device a need of disassembly is occurring (and, if necessary, disposal of the device), one should previously detach all powering and measuring voltages and other connections.

Dismounted device should be treated as electronic scrap and dispose it according to being in force regulations on waste management.

11. Guarantee and service

1. For the delivered device PUP KARED Sp. z o.o. is granting 2 years guarantee from the date of sale (unless notations of the separate agreement provide otherwise), on principles determined in a warranty card.

2. Manufacturer is granting the technical assistance at commissioning of the device and provides guarantee and post-warranty after sales service on conditions determined in the contract for this service.

3. Not obeying guidelines of this operation manual will cause the loss of guarantee rights.