User’s Manual

Check synchroscope type CSQ-2

4189340218K (UK)

• Multi function, precision LED synchronoscope
• Easy push-button programming of all set-points
• Very high user safety
• High immunity to harmonic distortion
• Dead bus functionality
• Special version for marine applications
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1. Warnings, legal information and notes to CE-marking

This manual gives general guidelines on how to install and operate the CSQ-2. Installing and operating the CSQ-2 implies work with dangerous currents and voltages. Therefore this should only be done by qualified personnel. DEIF A/S takes no responsibility for operation or installation. If there is any doubt about how to install or operate the system on which the CSQ-2 is measuring, the company responsible for the installation or the operation must be contacted.

The CSQ-2 is CE-marked with respect to the EMC directive for residential, commercial and light industry plus industrial environment. This covers all environment types where the CSQ-2 can normally be used.

The CSQ-2 is CE-marked with respect to the low-voltage directive for up to 300V phase to ground voltage, installation category (overvoltage category) III and pollution degree 2. 300V phase to ground voltage corresponds to 480V phase to phase voltage in 4-wire networks and 500V phase to phase voltage in 3-wire networks.

The package contains the following items:

- Check synchroscope CSQ-2 unit
- User’s manual
- Two fixing clamps
- A plugable connection (mounted on the unit)
- Cable for system status output (only marine version)

2. Application and functionality summary

The CSQ-2 check synchroscope is a microprocessor-based synchronising unit providing measurement of all relevant values for synchronising a generator to a net (busbar). It is used in any kind of installation where manual or semi-automatic synchronising is required.

In the CSQ-2 there is a possibility of adjusting the following synchronising requirements: The voltage difference between GEN and BB, the size of the phase window and the length of the synchronising pulse.

In addition to that there is an indication of ‘U\text{GEN} TOO HIGH’ or ‘U\text{GEN} TOO LOW’ (red LEDs), phase difference within the preset window ‘\varphi OK’, (yellow LED), and finally synchronising output active, ‘SYNC.’ (green LED).
Display/reading
The unit measures the two inputs voltages: Generator (GEN) and busbar (BB), respectively. The phase difference from GEN’s zero-crossing to BB’s zero-crossing is calculated by the processor and is shown on the LED circle, consisting of 36 red LEDs.

The red LEDs are only lit one at a time and its position indicates the phase difference between GEN and BB. The lit LED simulates the pointer tip of an analog pointer instrument. If the LED is lit in the 12 o’clock position, the phase difference is 0 degrees. In the 6 o’clock position, 180 degrees etc. With 36 LEDs the resolution is 10 degrees.

The movement of the lit LED’s position indicates the frequency difference between GEN and BB. If the indication is turning clockwise (too fast), the GEN frequency is too high in proportion to the BB frequency. If the indication is turning counter-clockwise, the proportion is inversed. The rate of the motion tells about the frequency difference. The faster the rotation, the bigger the frequency difference, e.g. 1 rotation per second = 1Hz. If the BB frequency is 50Hz and the rotation turns right, the GEN frequency will be 51Hz in this example.

If the frequency difference between GEN and BB is becoming too big (>3Hz), the circular motion stops and a LED will be lit at the “too fast” or “too slow” mark, dependent on which direction the GEN frequency has to be adjusted to.

Normal synchronising
The unit automatically calculates the synchronising parameters to check if there is the required space for the synchronising inside the preset phase window. These calculations compare the frequency difference with tR and the size of the phase window. When tR is set to ∞, td can be set by the user and is then included in the calculations instead of tR.

If the ∆ϕ window is set symmetrically, both under-frequency synchronising and over-frequency synchronising is possible.

Under- or over-frequency synchronising
When the ∆ϕ window is set asymmetrically the following functionality is possible:

- If the ∆ϕ window is set asymmetrically with a higher positive than negative ∆ϕ value, only synchronising with the generator input at lower frequency than the busbar input is possible (under-frequency synchronising).

- If the ∆ϕ window is set asymmetrically with a lower positive than negative ∆ϕ value, only synchronising with the generator input at higher frequency than the busbar input is possible (over-frequency synchronising).

Note:
This function is not active with tR set to ∞.
Dead bus synchronising
When the dead bus function is set, the synchronising relay will be activated and the green LED (SYNC) will be lit, when the busbar voltage is below the dead busbar preset level and the GEN voltage exceeds 80% of nominal value.

Power up reset
The unit will operate when the GEN voltage exceeds 80% of the nominal value. Below this level no functionality is obtained.

µP supervision output
Due to the demands from the classification societies (GL) a special optocoupler output has been added on the marine version.

From this output it is possible to supervise the internal microprocessor (µP).

If an error is present, the output changes state from a low to a high impedance (open collector output).
3. Operation of display, pushbuttons and LEDs

To get access to the settings, remove the front frame and the front foil.

The CSQ-2 can be operated in two different modes: "Normal mode" and "setting mode". Normal mode is used to display measuring values, and setting mode is used to view the settings or change them to the desired functionality.
3.1 LEDs
The CSQ-2 has the following LEDs on the fronts showing different operating information.

LEDs on primary front (normal mode):

<table>
<thead>
<tr>
<th>LED</th>
<th>Colour</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circle</td>
<td>Red</td>
<td>The lit LED in the circle shows the phase difference between GEN and BUSBAR</td>
</tr>
<tr>
<td>SYNC.</td>
<td>Green</td>
<td>All preset sync. parameters are OK, and the output relay is activated</td>
</tr>
<tr>
<td>( \phi ) OK</td>
<td>Yellow</td>
<td>The phase difference between GEN and BUSBAR is within the preset window</td>
</tr>
<tr>
<td>( U_{GEN} ) TOO HIGH</td>
<td>Red</td>
<td>The voltage difference between GEN and BUSBAR is outside the preset range. ( U_{GEN} ) is too high</td>
</tr>
<tr>
<td>( U_{GEN} ) TOO LOW</td>
<td>Red</td>
<td>The voltage difference between GEN and BUSBAR is outside the preset range. ( U_{GEN} ) is too low</td>
</tr>
</tbody>
</table>

LEDs on secondary front (setting mode):

<table>
<thead>
<tr>
<th>LED</th>
<th>Colour</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circle</td>
<td>Red</td>
<td>Parts of the circle are used as scales for the different settings</td>
</tr>
<tr>
<td>( \Delta \phi )</td>
<td>Yellow</td>
<td>Shows that the ( \Delta \phi ) scale is active</td>
</tr>
<tr>
<td>( t_d )</td>
<td>Yellow</td>
<td>Shows that the ( t_d ) scale is active. Please notice that ( t_d ) only becomes active with ( t_R ) set to ( \infty )</td>
</tr>
<tr>
<td>( t_R )</td>
<td>Yellow</td>
<td>Shows that the ( t_R ) scale is active</td>
</tr>
<tr>
<td>( \Delta U )</td>
<td>Yellow</td>
<td>Shows that the ( \Delta U ) scale is active</td>
</tr>
<tr>
<td>( U_{bus} )</td>
<td>Yellow</td>
<td>Shows that the ( U_{bus} ) scale (dead-bus) is active</td>
</tr>
</tbody>
</table>

For further information about the settings, please see appendix 1.
3.2 Settings

MODE:

NORMAL

\( \Delta U_{\text{max}} \)

\( \Delta U_{\text{min}} \)

SET/VIEW \( \Delta \varphi \) \( \text{pos} \)

SET/VIEW \( \Delta \varphi \) \( \text{neg} \)

SET/VIEW \( tr \)

\( tr = \infty \)

YES

NO

SET/ACTIVATE DEAD-BUS

SAVE automatically

NORMAL
Operation
The operation occurs via the secondary foil accessible when the primary foil/front frame is removed. The operation occurs by means of 3 pushbuttons: Mode (toggle), up arrow (▲) and down arrow (▼).

Control of settings
The mode button is held down for about 2-3 seconds to obtain the setting mode. This is confirmed by the fact that the LED is lit at the ΔU scale and that the setting of the ΔU max. parameter can be read on the matching scale. With ▲ and ▼ the setting can be changed.

For every subsequent push on the mode button, a change to the next parameter occurs. These can be read and changed in a corresponding way. When mode is pushed after the last parameter, one returns to normal mode.

When leaving the last setting menu, the LED circle "rotates" to indicate that the current setting has been saved automatically.

Please notice that the preset window, ΔU and Δϕ, is divided into two separate settings, making asymmetrical setting of this parameter possible.

Also please notice that if the settings are changed unintentionally, these are saved when the setting mode is left.

Change of Δϕ range
The normal range of Δϕ is -20°...-5° and 5°...20° in 1° steps.

This can be changed to -40°...-10° and 10°...40° in 2° steps.

Step down to the 20° point with the down arrow button. While pressing the down arrow button, press the up arrow button and the scale will change from normal range to the scale 2 x normal range. Press the up arrow button to return to normal range. While pressing the up arrow button, press the down arrow button, and the scale will change from 2 x normal range to normal range. Please notice that the 2 x normal range mode is indicated on the LED circle by activation of 2 LEDs each time Δϕ is changed.

Factory settings
When the product is delivered from the factory, the following basic settings will be set:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔU:</td>
<td>5% of ±UBB</td>
</tr>
<tr>
<td>tR:</td>
<td>0.5 sec.</td>
</tr>
<tr>
<td>Δϕ:</td>
<td>±10°</td>
</tr>
<tr>
<td>Dead bus:</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Restorage of factory settings
Activate the two arrow buttons simultaneously. While doing this hold down the mode button for approximately 5 seconds. Then the LED circle will light up and rotate to indicate that the factory settings have been restored.
4. Terminal list

4.1 Overview of the terminals

<table>
<thead>
<tr>
<th>Terminal no.</th>
<th>Signal symbol</th>
<th>Signal name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>R (L1)</td>
<td>Busbar voltage</td>
</tr>
<tr>
<td>2</td>
<td>S (L2)</td>
<td>Busbar voltage</td>
</tr>
<tr>
<td>3</td>
<td>SYNC.</td>
<td>Relay output</td>
</tr>
<tr>
<td>4</td>
<td>SYNC.</td>
<td>Relay output</td>
</tr>
<tr>
<td>5</td>
<td>R (L1)</td>
<td>Generator voltage</td>
</tr>
<tr>
<td>6</td>
<td>S (L2)</td>
<td>Generator voltage</td>
</tr>
</tbody>
</table>

Only on marine version:

<table>
<thead>
<tr>
<th>System status circuit off</th>
<th>+ open collector</th>
<th>- open collector</th>
</tr>
</thead>
<tbody>
<tr>
<td>= failure</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Rear view of the unit:

![Rear view of the unit](image_url)
5. Wiring diagrams

5.1 AC input connections
When ordering the CSQ-2, the correct range of voltage inputs must be specified. They must be connected as shown below.

5.1.1 Connection diagram

Note 1:
When the CSQ-2 is applied to emit a “ready to sync.” signal (\( t_R \) is set to \( \infty \)), and it is not directly controlling closing of the breaker, it is necessary to connect the CSQ-2 immediately before the ready signal is required, as the CSQ-2 disables check of the voltage difference (\( \Delta U \)) when the internal synchronising relay is activated.
6. Commissioning

Before commissioning: Check phases for correct voltage and correct direction of rotary (phase sequence).

Warning: Incorrect voltage may lead to malfunction and damage of the unit.

7. Technical data

Accuracy: ±2° (electrical degrees)

Resolution: 10° (36 LEDs)

Settings, range: Δφ: ±5...20° in 1° steps or ±10...40° in 2° steps
ΔU: ±1...10% in 1% steps
tR: 0...1 sec. in 0.1 sec. steps or ∞
td: 0...1 sec. in 0.1 sec. steps
Ubus offset: Off or 4 levels of noise suppression (dead bus)

Max. frequency difference: No limit

Input range (UN): 100...127V AC (115V AC) or 220...240V AC (230V AC) or 380...415V AC (400V AC) or 440...450V AC (450V AC)

Busbar input: Load: 2kΩ/V

Generator input: (Max. 2VA). Also supply for the unit

Max. input voltage: 1.2 x UN, continuously
2 x UN for 10 sec.

Frequency range: 40...70Hz (supply)

Relay contact: 1 SPST-NO-contact


Life mechanical: 2 x 10⁷

Life electrical: 1 x 10⁵ (nominal value)
Optocoupler output: System status off = failure
   NpN optocoupler output
   Max. 40V, 10mA
   2 wires AWG 20 (red/black)
   30 mm length
   (Only in marine version)

Temperature: -10...55°C (nominal)
   -25...70°C (operating)
   -40...70°C (storage)

Temperature drift: Set-points:
   Max. 0.2% of full scale per 10°C

Galvanic separation: Between inputs and outputs
   2.2kV - 50Hz - 1 min.

Climate: HSE, to DIN40040

EMC: According to EN50081-1/2, EN50082-1/2,
   SS4364503 (PL4) and IEC255-3

Connections: Max. 2.5 mm² (single-stranded)
   Max. 1.5 mm² (multi-stranded)

Materials: All plastic parts are self-extinguishing to UL94 (V0)

Protection: Front: IP52. Terminals: IP20
   According to IEC529 and EN60529

Type approval: For current approvals please see www.deif.com
   (Only valid for marine version)

Dimensions: Please see drawing in section 8

Panel cut-out: 91 x 91 ±1 mm

Weight: < 0.35 kg
8. Dimensions

All dimensions in mm

9. Order specifications
Input voltage and type must be specified when ordering the CSQ-2.

Order specification for the CSQ-2 consists of the following:

CSQ-2 - $U_N$ - type

where $U_N$ and type are as follows:

<table>
<thead>
<tr>
<th>Code</th>
<th>Function</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>$U_N$</td>
<td>Input voltage</td>
<td>&quot;115V&quot;: (100…127V AC input range)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot;230V&quot;: (220…240V AC input range)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot;415V&quot;: (380…415V AC input range)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot;450V&quot;: (440…450V AC input range)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>“Land”: Means the land version without GL approval. This is the standard version.</td>
</tr>
<tr>
<td></td>
<td>“Marine”: Means the marine version with GL approval and equipped with an additional output for surveillance.</td>
</tr>
</tbody>
</table>

Example of an order specification for the CSQ-2

CSQ-2 – 415V – Marine
Appendix 1: Setting and parameters for synchronising

Settings

\( \Delta U \)
Here the allowed relative voltage difference between GEN and busbar is adjusted. The regulating range is \( \pm 1 \ldots 10\% \) in steps of 1\%. The adjustment is made individually for \( \Delta U_{\text{MIN}} \) and \( \Delta U_{\text{MAX}} \), so asymmetrical adjustment is possible. The setting is done according to the following formula:

\[
\Delta U_{\text{MIN}}, \Delta U_{\text{MAX}} = \frac{(U_{\text{GEN}} - U_{\text{BUSBAR}}) \times 100}{U_{\text{BUSBAR}}}
\]

If the preset value is exceeded, one of the two \( U_{\text{GEN}} \) LEDs will emit red light, and synchronising is not possible.

If the generator voltage is too low, the \( U_{\text{GEN}} \) too low LED will be lit.
If the generator voltage is too high, the \( U_{\text{GEN}} \) too high LED will be lit.
If both the \( U_{\text{GEN}} \) LEDs are lit simultaneously, there is an over-voltage error on the input. In this case, disconnect the unit and check the applied voltage level!

\( \Delta \phi \)
Here the phase window is adjusted, in which synchronising can take place. The adjustment starts from \( \pm 5^\circ \) and the window can open symmetrically or asymmetrically around this value.
The regulating range is \(-20^\circ \ldots -5^\circ \) and \( 5^\circ \ldots 20^\circ \), in 1\(^\circ \) steps or \(-40^\circ \ldots -10^\circ \) and \( 10^\circ \ldots 40^\circ \), in 2\(^\circ \) steps.

\( t_R \)
Here the length of the pulse for the synchronising relay is adjusted.
The regulating range is 0...1 sec. in steps of 0.1 sec. or \( \infty \).
This function makes it possible to adjust the synchronising pulse according to the external breakers demands (closing time).

For special purposes it is also possible to adjust \( t_R \) to \( \infty \) (infinite). This setting will (after \( t_d \) has expired) provide a synchronising pulse as long as the following conditions are met:

- Phase is inside the phase window
- Voltage > 70\% of \( U_{\text{NOMINAL}} \)

\( t_d \)
Here the time is adjusted, in which the phase difference must be inside the preset synchronising window to allow SYNC. The regulating range is 0...1 sec. in steps of 0.1 sec.
\( t_d \) is only activated if \( t_R \) is set to \( \infty \).
Dead bus
The possibility of closing the circuit breaker even though the busbar voltage is missing. There is an extra adjustment, $U_{BUS}$, where the level of dead busbar can be set. This facility makes dead bus synchronizing possible, even though there is noise on the busbar. The regulating range is off or 10...40% of $U_N$ in steps of 10%.

<table>
<thead>
<tr>
<th>Setting</th>
<th>Dead bus function $U_{BUS}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFF</td>
<td>De-activated</td>
</tr>
<tr>
<td>10</td>
<td>Activated within the range 15-25% of actual generator voltage &gt; 70%</td>
</tr>
<tr>
<td>20</td>
<td>Activated within the range 25-30% of actual generator voltage &gt; 70%</td>
</tr>
<tr>
<td>30</td>
<td>Activated within the range 30-40% of actual generator voltage &gt; 70%</td>
</tr>
<tr>
<td>40</td>
<td>Activated within the range 40-50% of actual generator voltage &gt; 70%</td>
</tr>
</tbody>
</table>

Please notice that this setting is a coarse step regulation for suppression of possible noise on the busbar. The scale 10-20-30-40 should therefore be considered more as a 4 level noise suppression than as an accurate measuring setting.

Example:
The example is based on a 100V busbar system.

The dead bus setting is chosen to 10. When the generator voltage is higher than 70V, the CSQ-2 is activated, see note 1 below. When the dead bus function is activated, the CSQ-2 will check the busbar voltage. If this is below 15...25V, the CSQ-2 will send a closing signal to the breaker. In some cases where long wires (busbars) are connected to the CSQ-2, humming or noise picked up by the dead busbar can result in a higher input voltage than 25V. To avoid that, adjust the setting for dead bus to 20 and try again. If the humming is very high, a setting of 30 or 40 can be necessary to prevent humming (noise) to interfere with the dead bus function. If the dead bus function is activated and the setting is 10, and the humming is higher than 15...25V but below 30V, the CSQ-2 will only activate the $\Delta U$ LED indicating that the generator voltage is too high. If the humming is higher than 30V, the CSQ-2 will start to indicate the frequency and phase relationship by activating the LED circle. No sync. pulse will be transmitted because the $\Delta U$ voltage LED will still be active, indicating that the voltage difference is too high. During commissioning this must be observed to make sure that the dead bus noise suppressor is set correctly. After the breaker has been closed, the sync. relay will stay on until the timer $t_R$ expires (0...1 sec). When $t_R$ expires, the 12 o’clock position and the $\varphi$ OK LED will be illuminated. If infinite sync. relay pulse is chosen, the sync. pulse will stay on also after the breaker is closed, this is indicated by all 3 LEDs in 12 o’clock position being lit.

Note 1:
The CSQ-2 is power supplied from the generator input, the busbar input is only for measuring.
Guidelines for setting of the CSQ-2

Visual representation of the parameters
The figure below shows the different parameters:

Commissioning
Normally \( t_R \) is adjusted so it equals the circuit breakers closing time and \( \Delta \phi^-/\Delta \phi^+ \) to max. allowed synchronising error.

Please notice that the CSQ-2 calculates space for \( t_R \) (breaker closing time) within the chosen \( \Delta \phi \) window at the actual \( \Delta f \) (slip frequency). Therefore the max. synchronising error will never exceed the chosen \( \Delta \phi \) window.

Calculation example
The breaker closing time is 200mS, and \( t_R \) is chosen to 200mS. The phase window is set symmetrically to \( \pm 10^\circ \) (electrical degrees). Then the max. \( \Delta f \) can be calculated using the following formula:

\[
\Delta f = \frac{(\Delta \phi^-) + (\Delta \phi^+)}{360 \times t_R}
\]

\[
\Delta f = \frac{10 + 10}{360 \times 0.2} = 0.278\text{Hz}
\]

Synchronising relay pulse will not be emitted if \( \Delta f \) exceeds 0.278Hz.
Calculation of the actual synchronising error – not to be mistaken for the max. synchronising error which is solely determined by the chosen $\Delta \phi$ window

The next examples apply to situations where $t_R$ is set in the range 0.1...1 sec.

Example:
With a slip frequency ($\Delta f$) of 0.1Hz the phase changes with a rate of 36°/sec. If $\Delta \phi$ is set to $\pm 10^\circ$ and $t_R$ is set to 0.2 sec. = breaker closing time, the actual synchronising error can be calculated.

The moment the phase is within the set phase window ($\Delta \phi$), the relay of the CSQ-2 is activated on condition that there is space for the chosen $t_R$, in this case 0.2 sec. If $\Delta f$ is too big, it will cause lack of space for the chosen $t_R$ time within the chosen $\Delta \phi$ window.

Example 1:
With a phase change of 36°/sec. the phase will change 7.2° during the 0.2 sec. This means that we can now calculate the phase displacement at the exact moment when the breaker closes. $\Delta \phi$ is set to -10° and +10°. The CSQ-2 relay will be activated -10° before top (12 o’clock position), and after 7.2° the breaker closes which means that the breaker closes 10° - 7.2° = 2.8° before top, that is an actual synchronising error of -2.8°. Applying the formula on page 17, the max. $\Delta f$ with the shown settings can be calculated to be 0.277Hz.

Example 2:
If we assume that the slip frequency in the actual case is 0.2Hz, the phase changes with a rate of 72°/sec. With a phase change of 72°/sec. the phase will change 14.4° during the 0.2 sec. which gives a synchronising error of 10° - 14.4° = -4.4°. The negative result means that the breaker closed 4.4° after top, that is an actual synchronising error of +4.4°.

Example 3:
The same as examples 1 and 2, but with a slip frequency of 0.3Hz = 108°/sec. At $t_R = 0.2$ sec. the phase will change 21.6°. As the $\Delta \phi$ window is set to $\pm 10^\circ$, the CSQ-2 will calculate that there is no longer space for a $t_R$ pulse of 0.2 sec., and therefore no relay pulse is emitted.

General formula for the above-mentioned:
Actual synchronising error = ($\Delta \phi^-$) - 360 x $\Delta f$ x breaker closing time ($t_R$).

Alternatively at negative slip frequency:
Actual synchronising error = ($\Delta \phi^+$) - 360 x $\Delta f$ x breaker closing time ($t_R$).

If the result is negative, the synchronising will take place after top (0°) provided that there is space for $t_R$ within the $\Delta \phi$ window.

If you want to avoid synchronising after top, $\Delta \phi$ is set asymmetrically. At positive slip frequency ($\Delta f$) as in the shown example a setting of $\Delta \phi^-$ to -10° and $\Delta \phi^+$ to +5° would have as a result that synchronising after top of more than 5° would not be possible.
The length of the relay pulse $t_R$ can never be set to a lower value than the breaker closing time, whereas $t_R$ can be set to a higher value if you want the max. slip frequency ($\Delta f$) to be lower to limit the rush of current of the breaker (the generators) in connection with the synchronising.

Example:
In the light of the above-mentioned examples $t_R$ is changed to 0.4 sec. With a slip frequency ($\Delta f$) of 0.1Hz = 36°/sec. and $t_R = 0.4$ sec. the phase changes 14.4° during the 0.4 sec. If $\Delta \phi$ is set to ±10°, the CSQ-2 will calculate that there is space for $t_R$. With this setting the synchronising error will be identical with the synchronising error in example 1 (-2.8°) as the breaker closing time is the same (0.2 sec.). But the max. $\Delta f$ can now only be 0.138Hz and not, as in example 1, 0.277Hz. The max. slip frequency ($\Delta f$) could also be controlled by setting $\Delta \phi$ differently. If $\Delta \phi$ was set to ±5° instead of ±10° the max. $\Delta f$ would be 0.138Hz at $t_R = 0.2$ sec. With this setting and a $\Delta f$ of 0.1Hz, the actual synchronising error will be +2.2°. Please notice that the breaker now closes 2.2° after top and not, as in example 1, 2.8° before top. The choice of setting must be based on the knowledge of the actual installation in which the CSQ-2 is applied. But the examples are to show that $t_R$ and $\Delta \phi$ are inextricably connected and influence the same parameters, but with different results as to the calculation of the actual synchronising error.

If $t_R$ is set to infinite ($\infty$), the max. allowable $\Delta f$ can no longer be controlled by means of $t_R$. When $t_R$ is set to infinite, the setting of $t_d$ is automatically activated. Infinite $t_R$ is primarily used where the CSQ-2 is applied as supervision of an automatic synchronising system or in connection with closing of a tie breaker where you want to check frequency, phase and voltage to be within certain values before the breaker is closed.

The setting of $t_d$ is to be calculated from $\Delta \phi$ and the estimated max. allowable $\Delta f$.

$$t_d = \frac{(\Delta \phi^-) + (\Delta \phi^+)}{360 \times \Delta f}$$

Example 1:
$\Delta \phi$ is set to ±7°, and a max. $\Delta f$ of 0.05Hz at the moment of synchronising is estimated to be allowable.

$$t_d = \frac{| -7 | + 7 |}{360 \times 0.05}$$

$t_d = 0.77$ sec. ~ 0.8 sec.

Please notice that when $t_R$ is set to infinite ($\infty$), the synchronising pulse (the relay contact of the CSQ-2) is interrupted the moment the phase is outside the set phase window. As the timer $t_d$ starts the moment the phase is within the set phase window $\Delta \phi$, and is to expire in the period the phase is still within the phase window before the synchronising pulse is emitted, it means in the shown example that with an actual $\Delta f$
of 0.049Hz the synchronising pulse would only be 18 msec. To avoid transmission of such a short synchronising pulse, the CSQ-2 performs a calculation based on $\Delta f$ and the actual phase window to make room for a synchronising pulse of at least 100 msec. Referring to example 1, 100 msec must be subtracted from the calculated $t_d$ to allow a max. $\Delta f$ of 0.05Hz.

Function in particular situations:
In connection with test “on desk” the CSQ-2 is normally connected to the same supply point so that frequency and phase are completely identical on the generator input and the busbar input. At this test form the following must be noticed:

The first time the CSQ-2 is connected, synchronising pulse is emitted whether the $\Delta \phi$ window is set symmetrically or asymmetrically. If only the busbar input is interrupted subsequently (the CSQ-2 is supplied with auxiliary voltage from the generator input), synchronising pulse is only emitted if the interruption has lead to the result that the $\Delta \phi$ window was left in connection with the interruption (occurs if the interruption results in a noise pulse).

If $\Delta \phi$ is set asymmetrically so that only e.g. positive $\Delta f$ is accepted, and $\Delta f$ changes sign (inverse direction) after the phase between generator and busbar is within the phase window, the synchronising pulse is not interrupted until the $\Delta \phi$ window is left, even if $\Delta f$ has changed sign to negative $\Delta f$.

If $\Delta f$ is changed to correct direction of rotation after the phase is within the phase window, the CSQ-2 calculates if there is space for $t_R$ (the synchronising pulse), and in that case synchronising pulse is emitted.