Zone Selective Interlocking (ZSI)

Functionality and Structure of ZSI
For short circuit and ground fault as well

Application Guide
Selective tripping?

**Objective:**
Selective tripping with minimum short-circuit duration, irrespective of the grading level in which the short-circuit occurs.

**Selectivity:**
A system with several protective devices connected in series is referred to as **selective** if - in the event of a short-circuit - **only** the protective device (example: Q22) located directly in front of the fault location responds and clears the short-circuit by itself. **Unaffected branch circuits** continue to be supplied.
Selectivity achieved via the short-time delayed short-circuit release

Solution:
Example of time grading using a 3WL1

The 3WL is given a different delay time $t_{sd}$ in the individual grading levels.

The objective is to delay the tripping of the upstream circuit breakers for the short-circuit duration until the circuit breaker closest to the fault clears the short-circuit.
Selectivity achieved via the short-time delayed short-circuit release

**Problem 1:**
In this example, a grading level is missing from the time grading

**Q11 and Q21 trip simultaneously**

The reason:
- a) No time grading
- b) No current grading possible
Selectivity achieved via the short-time delayed short-circuit release

**Problem 2:**

In the event of a short-circuit, e.g. directly after Q11, Q11 must still wait for the time $t_{sd}$ (400ms), even though the circuit-breaker could clear the short-circuit immediately.

The result is that the system is exposed to the short-circuit for an unnecessarily long time.
Selectivity via the ZSI function?

**Zone Selective Interlocking (ZSI)**
in the event of short-circuits and ground faults

One possible solution to ensure selectivity for circuit breakers easily and safely is the ZSI function of the SENTRON 3WL and the SENTRON 3VL.

3WL ZSI CubicleBus module

3VL COM20/21
Structural principle of the ZSI function

- Each circuit breaker features a ZSI module
- The ZSI modules are connected to one another
- The ZSI output (ZSI OUT) ①, example of grading level #2, is connected to the ZSI input (ZSI IN) ②, example of the upstream grading level #1
- ZSI modules within one grading level are connected in parallel
- Integration of a coupling switch is possible
- Integration of medium voltage is possible
- No configuration is required
Basic procedure of the ZSI function in the event of a short-circuit

From the viewpoint of Q2:
Short-circuit detected case a) or b)

1. ZSI OUT
   Set signal!

   Short-circuit current in the instantaneous range?

   Yes
   - Tripping after approx. 20 ms
   - ZSI IN signal detected?
     - Yes (case b)
     - t_{zd} = 300 ms start
   - No (case a)
     - t_{ZSI} = 50 ms start
     - Tripping after approx. 50 ms

   No
   - Short-circuit still present?
     - Yes
     - Shorter tripping time via ZSI with full selectivity
       - Tripping after approx. 300 ms*
     - No (no tripping)

* Applies to the reference point 12 x In. The tripping time can be longer for smaller short-circuit currents

No inherent circuit breaker times observed during the tripping
Basic procedure of the ZSI function in the event of a short-circuit

1. Short-circuit detected!
2. Set ZSI OUT signal to upstream Q1
3. Check whether the short-circuit current is greater than or equal to $I_i$ (response value of the instantaneous short-circuit release)? => If so, an instantaneous tripping operation occurs
4. Check whether a ZSI IN signal from the downstream Q3 is present?
5. No ZSI IN signal present! The tripping operation occurs with the time $t_{ZSI} = 50$ ms
6. A ZSI IN signal from Q3 detected. The time $t_{sd} = 300$ ms is started
7. A check is made to see whether circuit breaker Q3, which has also detected the short-circuit (ZSI IN signal), has cleared the short-circuit.

Thanks to ZSI, the tripping time of the circuit breakers, and therefore the load on the switchgear, is significantly reduced!
Basic procedure of the ZSI function in the event of a ground fault

From the viewpoint of Q2:
Ground fault detected case a) or b)

1. ZSI OUT  
   Set signal!

2. ZSI IN 
   signal detected?
   - Yes (case b)  
     - t_b = 400 ms  
     - start
     - Ground fault still present?  
     - Yes  
       - Tripping after approx. 100 ms
     - No
     - No tripping
   - No (case a)  
     - t_zsi = 100 ms  
     - start
     - Tripping after approx. 100 ms

Shorter tripping time via ZSI with full selectivity

No inherent circuit breaker times observed during the tripping
Basic procedure of the ZSI function in the event of a short-circuit or ground fault

**short-circuit**

<table>
<thead>
<tr>
<th>ZSI ON / OFF</th>
<th>S</th>
<th>ZSI-IN (1)</th>
<th>ZSI-OUT (2)</th>
<th>SD-Time</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFF</td>
<td>NO NO NO NO</td>
<td>tSD 300 ms</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OFF</td>
<td>YES NO</td>
<td>YES</td>
<td>tSD 300 ms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ON NO</td>
<td>YES NO</td>
<td>NO</td>
<td>tSD 300 ms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ON YES YES</td>
<td>YES YES</td>
<td>tSD 300 ms</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ON NO NO NO</td>
<td>tZSI 50 ms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ON YES NO YES</td>
<td>tZSI 50 ms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**ground fault**

<table>
<thead>
<tr>
<th>ZSI ON / OFF</th>
<th>GF</th>
<th>ZSI-IN (1)</th>
<th>ZSI-OUT (2)</th>
<th>SD-Time</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFF</td>
<td>NO NO NO NO</td>
<td>t_g 400 ms</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OFF</td>
<td>YES NO</td>
<td>YES</td>
<td>t_g 400 ms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ON NO</td>
<td>YES NO</td>
<td>NO</td>
<td>t_g 400 ms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ON YES YES</td>
<td>YES YES</td>
<td>t_g 400 ms</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ON NO NO NO</td>
<td>tZSI 100 ms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ON YES NO YES</td>
<td>tZSI 100 ms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Possible applications of the ZSI function

- In the event of a **short-circuit and a ground fault**
- Ensuring a **very short delay time** with full selectivity => typically 80 ms to a maximum of 90 ms ($t_{ZSI} + \text{mechanical tripping}$) in the event of a short-circuit
- $t_{ZSI} = 50 \text{ ms}$ (delay time) in the event of a short-circuit
- $t_{ZSI} = 100 \text{ ms}$ (delay time) in the event of a ground fault
- ZSI **localizes** the location of the short-circuit or ground fault
- **Reduction** of the loads / damage in the event of a short-circuit or ground fault in the system and for cables / lines
- **Mixed system design** with WL, VL, WN (not for new systems)
- **Integration of coupling switches**
- Integration of **existing system parts** (e.g. 3WN)
- Integration of the **medium-voltage circuit breaker** directly in front of the transformer
- Use in extensive, **decentralized energy supply systems**
- The "delay time" enables the integration of an additional, downstream protective device level **without ZSI connection**, provided that instantaneous tripping occurs
Benefits and advantages of the ZSI function

- **Selective tripping** for minimum short-circuit / ground fault duration
- **No parameterization** of the ZSI function required. → This prevents setting errors.
- **Optimization of cables**, since $t_d$ always = 50 ms +35 ms ($S^2k^2 > I^2t$, the requiring energy is only dependent on $I^2$, since $t_d$ = const. < 100 ms)
- ZSI – (blocking) signal is also set when the **instantaneous trip unit** (instantaneous release) trips
- Only the **circuit breaker directly upstream** from the fault location is switched off in the event of a short-circuit and/or a ground fault
- **Increasing the grading levels**, depending on the type of trip unit and the line length (maximum number of grading levels >20 with ETU 76B and $t_{sd}$ up to 4000 ms)
- Time **limitation of an arc fault short-circuit current** to less than 100 ms
- **Quick tripping time** of the upstream circuit breaker if the short-circuit is "skipped".
- ZSI module can at any time be **retrofitted without difficulty**, depending on the trip unit type
- Connection of **devices without ZSI** possible (lowest level, instantaneous tripping)
Why is it important to clear a short-circuit quickly?

The effect of the short-circuit increases as time progresses

- Thermal load on all equipment
  $\rightarrow I_{cw}$ for switching devices decreases considerably as time progresses
- High dynamic load on the switchgear
- Voltage dip during faulty operation of the other consumers
- Risk of persons getting an electric shock
  (touchable, electrically conductive external surfaces may be live)
- Risk for persons in front of the switchgear because of hot and toxic gases
- PE potential is increased near the short-circuit location,
  $\rightarrow$ risk for electronic parts
- Strong magnetic fields
  $\rightarrow$ Influence on auxiliary circuits and electronic signals
- Risk of arc faults and destruction of the switchgear
- Failure or destruction of the switching devices caused by overshooting of $I_{cw}$
Determining the settings for $t_{sd}$ in a ZSI system

In the event of a short-circuit, a circuit-breaker normally trips with a time of $t_{ZSI} = 50$ ms. The delay time $t_{sd}$ is only required in a ZSI system to compensate for the potential non-tripping of an upstream circuit breaker (reserve protection). (example on the following page)

- Last (downstream) circuit breaker (4) with ZSI
  **Setting for $t_{sd} = 0$ms**

- First upstream circuit breaker (3) with ZSI
  **Setting for $t_{sd} = 100$ms**
  50ms of delay time plus approx. 35ms of typical tripping time or 100ms minimum signal duration

- Second upstream circuit breaker (2) with ZSI
  **Setting for $t_{sd} = 150$ms**
  or rounded up to the next highest setting 100ms $t_{sd}$ plus 35ms typical tripping time of the first circuit breaker

- Every additional upstream circuit breaker (1)
  $t_{sd}$ **plus a maximum of 50ms** action time of the downstream circuit breaker

- Settings of the delay time for ground fault tripping analogous under observance of the corresponding delay time
Determining the settings for $t_{sd}$ in a ZSI system

Example of calculating the grading times

<table>
<thead>
<tr>
<th>For ETU25B ... ETU27B Without ZSI</th>
<th>For ETU 45B to 76B With ZSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t_{sd} = 400$</td>
<td>$ZSI = ON$</td>
</tr>
<tr>
<td>$t_{sd} = 300$</td>
<td>$t_{sd} = 200$</td>
</tr>
<tr>
<td>$t_{sd} = 200$</td>
<td>$t_{sd} = 150$</td>
</tr>
<tr>
<td>$t_{sd} = 100$</td>
<td>$t_{sd} = 100$</td>
</tr>
<tr>
<td>$t_{sd} = 0$</td>
<td>$t_{sd} = 0$</td>
</tr>
</tbody>
</table>

Arc quenching after approx.

- $35 + 400 = 435ms$
- $35 + 300 = 335ms$
- $35 + 200 = 235ms$
- $35 + 150 = 185ms$
- $35 + 100 = 135ms$
- $35 + 50 = 85ms$

Arc quenching after approx.

- $35 + 0 = 35ms$

The delay times which need to be set are reduced thanks to ZSI!
Technical conditions

- Technical requirements for the ZSI line:
  twisted in pairs; at least 0.75mm²; maximum length: 400m
  recommended type LSYCY 2 x 0.75mm²

- Line lengths of more than 400m are possible; this depends on the cable cross-section and the protection against negative influences such as electromagnetic or transient faults

- A "ZSI IN" cannot be connected to more than 20 "ZSI OUT" (downstream);
  ➞ no more than 20 downstream circuit breakers connected in parallel

- A "ZSI OUT" cannot be connected to more than 8 "ZSI IN" (upstream);
  ➞ no more than 8 upstream circuit breakers connected in parallel

- The 3WL ZSI module must always be the first CubicleBus module to be connected to the COM15 or the terminal strip –X8 (Cubicle Bus) of the 3WL
Withdrawal of the ZSI signal

- ZSI OUT in the event of a **short-circuit** after clearance of the short-circuit current, at the earliest after 100 ms, however
- ZSI OUT in the event of a **ground fault** after clearance of the short-circuit current, at the earliest after 100 ms, however
- MV OUT to the **medium voltage** after clearance of the short-circuit current, at the earliest after 500 ms, however
- The OUT signal is withdrawn after 3s at the latest
Example network without coupling switch
Example network with coupling switch without outgoing circuit breaker
Example network with coupling switch and outgoing circuit breaker
Example network with coupling switch and outgoing circuit breaker

Coupling switches are a grading level of their own

The connection for the COM10 is different.
Example network with medium voltage

Blocking signal to medium voltage.
ZSI module 3WL

Function via rotary coding switch

- **OFF** ZSI module deactivated
- **S** ZSI module only effective for short-time delayed short-circuit protection
- **G** ZSI module only effective for ground fault protection
- **S+G** ZSI module effective for short-time delayed short-circuit and ground fault protection
- **Test** Test position for checking ZSI functionality

- **TIE BRKR** Connection terminals for tie breaker
- **ZSI IN** Input for ZSI (blocking) signal -> this circuit breaker receives ZSI signal
- **ZSI OUT** Output for ZSI (blocking) signal -> this circuit breaker sends ZSI signal
- **MV OUT** Output for ZSI (blocking) signal for reporting to the medium voltage (floating contact; 50mA at 150 V AC/DC). Minimum signal duration 500ms
Test position ZSI

Test position on rotary coding switch:

- ZSI signal is permanently sent to the upstream circuit breaker
- Module additionally sends a signal to the connected 3WL. In this way, a communication connection can be tested. (As if the ZSI blocking signal were coming from the downstream circuit breaker)
- The "Test of the S settings" function allows a potential "feeling" for the set time $t_{sd}$.
  For $t_{sd} = 0$, $t_{ZSI} = 50$ ms applies

Test button on module:

- Temporary testing of the signal displays and outputs on the module itself.
- Identical to all CubicleBus modules
The **TIE BRKR** function (1, 2) ensure that even when the tie breaker is off, the **ZSI IN** signal (3, 4) directly transferred to the output **ZSI OUT** (5, 6). Without the TIE BRKR function the signal would not be forwarded.
3VL ZSI function

3VL ETU with rotary knob:
- Short-circuit: Standard setting for the short-circuit protection function is ZSI = OFF. The ZSI function must be activated via communication.
- Ground fault: Standard setting for the ground fault protection function is ZSI = OFF. The ZSI function must be activated via communication.

3VL ETU with LCD:
- Short-circuit: Standard setting is ZSI = OFF. The short-circuit protection function can be activated via the menu in the display or via communication.
- Ground fault: Standard setting is ZSI = OFF. The ground fault protection function can be activated via the menu in the display or via communication.
Required components, 3WL

**Short-circuit**

ETU45B + 3WL9111-0AT21-0AA0

**Ground fault**

For ETU45B
Local parameterization

3WL9111-0AT53-0AA0

For ETU76B
Local or remote parameterization

3WL9111-0AT56-0AA0

Current converter 1200 A / 1 A
Required components, 3VL

**Short-circuit**

- ETU10*
- ETU10M*
- ETU20*
- ETU30M*

**Ground fault**

- 3VL COM20/21
- ETU12*
- ETU22*

*3VL9000-8AU00
3VL9000-8AV00

* With communication function
ZSI for 3WL, 3VL, 3WN6 and 3WN1

- 3WL / 3VL functionally identical
- 3WN6 Functionally identical to 3WL / 3VL
- Connection points can be found in the manuals of the respective circuit breakers
- For the technical data of the ZSI system, the weakest part is decisive in each case e.g.: 3WN6 upstream => not more than 3 parallel 3WN6 instead of 8 parallel 3WL
Example: ZSI function in the event of a short-circuit

A)

\[ t_{sd} = 300 \text{ ms} \]

\[ t_{sd} = 200 \text{ ms} \]

\[ t_{ZSI} = 50 \text{ ms} \]

B)

\[ t_{sd} = 300 \text{ ms} \]

\[ t_{ZSI} = 50 \text{ ms} \]
Example: ZSI function in the event of a ground fault

A) $t_g = 500\text{ ms}$

$t_g = 400\text{ ms}$

$t_{ZSI} = 100\text{ ms}$

B) $t_g = 500\text{ ms}$

$t_{ZSI} = 100\text{ ms}$
Example: ZSI function in the event of a short-circuit

With ZSI and without ZSI function in grading level 3

$\text{ts}_d = 0 \text{ ms} \checkmark$

$\text{ts}_d = 100 \text{ ms}$

$\text{ts}_d = 100 \text{ ms}$

$\text{ts}_d = 300 \text{ ms}$

$\text{t}_{ZSI} = 50 \text{ ms}$

$\text{ZSI OUT}$

$\text{ZSI IN}$

$\text{ZSI OUT}$

$\text{Trip}$

$\text{Trip}$

$\text{Trip}$
# List of abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETU</td>
<td>Electronic Trip Unit</td>
</tr>
<tr>
<td>G</td>
<td>Ground fault protection</td>
</tr>
<tr>
<td>I</td>
<td>Instantaneous trip unit, instantaneous short-circuit tripping</td>
</tr>
<tr>
<td>I&lt;sub&gt;cw&lt;/sub&gt;</td>
<td>Rated short-time withstand current</td>
</tr>
<tr>
<td>I&lt;sub&gt;i&lt;/sub&gt;</td>
<td>Instantaneous short-circuit current</td>
</tr>
<tr>
<td>I&lt;sub&gt;n&lt;/sub&gt;</td>
<td>Nominal current</td>
</tr>
<tr>
<td>N</td>
<td>Neutral conductor</td>
</tr>
<tr>
<td>MV</td>
<td>Medium voltage</td>
</tr>
<tr>
<td>Q</td>
<td>Circuit breaker</td>
</tr>
<tr>
<td>S</td>
<td>Short-time delayed short-circuit protection</td>
</tr>
<tr>
<td>t&lt;sub&gt;d&lt;/sub&gt;</td>
<td>Delay time</td>
</tr>
<tr>
<td>t&lt;sub&gt;ZSI&lt;/sub&gt;</td>
<td>ZSI time = 50 ms (delay time)</td>
</tr>
<tr>
<td>t&lt;sub&gt;sd&lt;/sub&gt;</td>
<td>Delay time of the short-time delayed short-circuit protection</td>
</tr>
<tr>
<td>ZSI</td>
<td>Zone Selective Interlocking</td>
</tr>
<tr>
<td>ZSI&lt;sub&gt;s&lt;/sub&gt;</td>
<td>short-circuit identified and set ZSI OUTsignal</td>
</tr>
<tr>
<td>ZSI&lt;sub&gt;a&lt;/sub&gt;</td>
<td>ZSI active (ZSI time = 50 ms)</td>
</tr>
</tbody>
</table>
Thank you for your attention!

Rainer Huentemeier
Productmanager
IC LMV LV GP ACB&F

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Huentemeier / Pikulicki