Example to calculate the limit values for SS1 and SLS

Application description for SINAMICS G120
Example to calculate the limit values for SS1 and SLS

Warranty, liability and support

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Preposition

Aim of the application

This application was generated in order to give users the opportunity of being able to calculate the limit values for the SLS and SS1 safety functions.

This application shows how this calculation should be correctly made in order to avoid safety fault/error messages and to guarantee the maximum availability of the drive.

Scope

The following core issues are discussed in this application:

- General information to calculate the limit values for SLS and SS1
- Example to calculate the limit values for SLS and SS1

Exclusion

This application does not include a description of the following:

- Commissioning safety functions
- Possible applications
- Handling safety functions

It is assumed that readers have a basic knowledge about these subjects.

Reference to the Automation and Drives Service & Support

This article is from the Internet Application Portal of the Automation and Drives Service & Support. You can go directly to the download page of this document using this link.

Example to calculate the limit values for SS1 and SLS

ID-No: 24488874

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Application description

1 Overview and description of the functionality

The SINAMICS G120 is a modular drive inverter system that essentially comprises the two function units Control Unit (CU) and Power Module (PM).

When using the CU240S DP-F Control Unit you can use the following safety-relevant functions integrated in the drive inverter:

**SLS - Safely-Limited Speed**

According to IEC 61800-5-2

The drive inverter monitors a set motor speed limit (upper limit) without requiring any additional external components

- Limits and monitors the drive speed
- Guarantees the shortest response times when a fault condition develops as a result of independent and continuous monitoring
- A speed encoder is not required

**SS1 - Safe Stop 1**

According to IEC 61800-5-2

The drive inverter reduces the motor speed along a braking ramp down to standstill (zero speed) and continually monitors this braking operation without any additional external components

- The drive is quickly stopped, safely monitored
- Guarantees the shortest response times when a fault condition develops as a result of independent and continuous monitoring
- A speed encoder is not required
STO - Safe Torque Off

According to IEC 61800-5-2

- The drive inverter brings the drive into a safety-relevant torque-free condition
- The drive inverter protects the drive from accidentally starting (protection against restarting does not require electrical isolation between the motor and drive inverter).

SBC - Safe Brake Control

The drive inverter monitors the control of the electromechanical motor brake. The relay required for this function is available under Order No. [MLFB] 6SL3252-0BB01-0AA0.

- An external brake can be controlled in a safety-relevant fashion when using the Safe Brake Relay

The safety-relevant functions are either controlled using two fail-safe digital inputs (4 digital inputs that are evaluated in the CU 240S DP F through two channels in a fail-safe fashion) or via PROFIsafe in conjunction with a fail-safe CPU.

Information and restrictions

Please carefully note that the two SLS and SS1 safety-relevant functions cannot be used for loads that drive the motor or are permanently in the regenerative mode.

A "load that moves the drive or is permanently regenerating" is involved if the motor, when in a no-voltage state, is accelerated by the load it normally drives (e.g. lifting equipment, winders, wind turbines).

A perfectly functioning closed-loop control is a prerequisite for using the fail-safe functions. The drive (drive inverter + motor + driven load system) must be designed so that all of the operating cases associated with the particular application can be absolutely safely controlled and handled.

After the STO and SS1 safety functions have been activated, there is no electrical isolation between the line supply connected to the SINAMICS G120 and the motor. If this electrical isolation is specified for your application then you must install an appropriate line contactor in front (upstream) of the SINAMICS G120.
2 Calculating the limit values for SS1 and SLS

When parameterizing the SLS and SS1 safety functions, several limit values should be defined in the so-called envelope curve. To do this, all of the safety calculation formulas must be taken into account that help to avoid errors when parameterizing safety functions or to avoid resulting fault/error messages. This calculation is described in detail in the following.

2.1 Parameterizing the envelope curve for SLS and SS1

When parameterizing the envelope curve for SLS and SS1, the following minimum tolerances should be observed with P9680/P9880 and P9691/P9891 in order to guarantee the maximum availability of the drive.
1. Upper tolerance range for the SLS P9691
   The upper tolerance range for the SLS P9691 should be set to
   \[ P9691 \geq 1.15 \cdot P9690 + F_{slip} \]

   This is means that the minimum frequency tolerance is defined as
   \[ \Delta F = P9691 - P9690 - F_{slip} \]
   whereby
   \[ F_{slip} = r0330 \cdot P0310 \]

   This parameterization prevents failures due to measuring errors. It should
   be noted that P9691 must be set if SLS was not parameterized.

2. Resulting frequency tolerance \( \Delta F_{high} \)
   The resulting frequency tolerance \( \Delta F_{high} \) is, due to the minimum frequency
   tolerance at high frequencies, given by:
   \[ \Delta F_{high} \geq 0.15 \cdot F_{max} - \Delta F \]
   whereby \( F_{max} \) is defined to be the maximum frequency when initializing
   SLS or SS1.

3. Resulting frequency tolerance \( \Delta F_{low} \)
   The resulting frequency tolerance \( \Delta F_{low} \) is, due to the minimum frequency
   tolerance at low frequencies, given by:
   \[ \Delta F_{low} \geq m / D - \Delta F \]
   Whereby gradient \( m \) is defined as \[ m = 200 / P9681 \]

   The value for \( D \) in the formula above is calculated as follows:
   SLS parameterized: \( D = 2 \cdot P9690 \)
   SS1 parameterized: \( D = 2 \cdot P9682 \)
   SLS and SS1 parameterized: \( D = 2 \cdot min \{ P9682, P9690 \} \)
4. Delay $\Delta F_{delay}$

The valid delay $\Delta F_{delay}$ is given as a maximum of

$$\Delta F_{delay} = \max [0, \Delta F_{low}, \Delta F_{high}]$$

5. Minimum delay of the braking ramp

The minimum delay of the braking ramp can be calculated using

$$P9680 \geq \Delta F_{delay} / m$$

The envelope curve for SS1 and SLS is obtained from a time delay (P9680) in the t direction and an additional frequency tolerance $\Delta F$ in the F direction.
3  Example: Calculating the safety formulas

The safety formulas for a 1LA7060-4AB10-Z motor and for the factory settings of the safety parameters are calculated in the following example. The technical motor data and the values to calculate the required safety parameters are listed in the following tables.

Table 3-1  Technical data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Parameter text</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>P0300</td>
<td>Selects the motor type</td>
<td>1; induction motor</td>
</tr>
<tr>
<td>P0304</td>
<td>Rated motor voltage</td>
<td>230/400 [V] ∆/Y</td>
</tr>
<tr>
<td>P0305</td>
<td>Rated motor current</td>
<td>0.73/0.42 [A]</td>
</tr>
<tr>
<td>P0307</td>
<td>Rated motor power</td>
<td>0.12 [kW]</td>
</tr>
<tr>
<td>P0308</td>
<td>Rated motor power factor</td>
<td>0.75</td>
</tr>
<tr>
<td>P0310</td>
<td>Rated motor frequency</td>
<td>50 [Hz]</td>
</tr>
<tr>
<td>P0311</td>
<td>Rated motor speed</td>
<td>1350 [rpm]</td>
</tr>
<tr>
<td>r0313</td>
<td>Motor pole pair number</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 3-2  Factory settings of the safety parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Parameter text</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>P9681</td>
<td>SI braking ramp, ramp-down time</td>
<td>10 [s]</td>
</tr>
<tr>
<td>P9682</td>
<td>SI minimum speed to detect standstill (zero speed)</td>
<td>5.0 [Hz]</td>
</tr>
<tr>
<td>P9690</td>
<td>SI setpoint for SLS</td>
<td>10.0 [Hz]</td>
</tr>
</tbody>
</table>

1. Upper tolerance range for SLS P9691

The slip frequency is calculated from:

\[ F_{slip} = r0330 \cdot P0310. \]

whereby \( r0330 \) is the rated motor slip

- \( r0330 = (P0310 - P0311 \cdot r0313 / 60) / P0310 \cdot 100\% \)
- \( F_{slip} = (50 [Hz] - 1350 [rpm] \cdot 2 / 60) / 50 [Hz] \cdot 100\% \cdot 50 [Hz] \)
  \[ = 5 [Hz] \text{ or } 10 \% \text{ of } 50 [Hz] \text{ (P2000 = 50 [Hz])}; \]

The upper tolerance range for SLS P9691 is therefore:
Example: Calculating the safety formulas

Example to calculate the limit values for SS1 and SLS

\[ P9691 \geq 1.15 \cdot P9690 + F_{slip}, \quad \text{or} \]
\[ P9691 \geq 1.15 \cdot 10 \,[\text{Hz}] + 5 \,[\text{Hz}], \]
\[ P9691 \geq 16.5 \,[\text{Hz}]; \]

Here, parameter P9691 should be selected, e.g. \( P9691 = 16.5 \,[\text{Hz}] \) (or 17 [Hz]).

The minimum frequency tolerance is calculated from:
\[ \Delta F = P9691 - P9690 - F_{slip}, \quad \text{or} \]
\[ \Delta F = 16.5 \,[\text{Hz}] - 10 \,[\text{Hz}] - 5 \,[\text{Hz}] = 1.5 \,[\text{Hz}] \]

2. Resulting frequency tolerance \( \Delta F_{high} \)

The formula to define the upper frequency tolerance \( \Delta F_{high} \) is as follows:
\[ \Delta F_{high} \geq 0.15 \cdot F_{max} - \Delta F; \]

If e.g. \( F_{max} = 50 \,[\text{Hz}] \), then the following is obtained:
\[ \Delta F_{high} \geq 0.15 \cdot 50 \,[\text{Hz}] - 1.5 \,[\text{Hz}], \]
\[ \Delta F_{high} \geq 6 \,[\text{Hz}] \]

3. Resulting frequency tolerance \( \Delta F_{low} \)

The formula to determine the lower frequency tolerance \( \Delta F_{low} \) is:
\[ \Delta F_{low} \geq \frac{m}{D} - \Delta F \]

Gradient \( m \) is calculated as follows:
\[ m = \frac{200}{P9681} = \frac{200 \,[\text{Hz}]}{10 \,[\text{s}]} = 20 \,[\text{Hz/s}] \]

The value \( D \) for -

- SLS parameterized - \( D = 2 \cdot P9690 = 2 \cdot 10 \,[\text{Hz}] = 20 \,[\text{Hz}] \)
- SS1 parameterized - \( D = 2 \cdot P9682 = 2 \cdot 5 \,[\text{Hz}] = 10 \,[\text{Hz}] \)
- SLS and SS1 parameterized - \( D = 2 \cdot \text{min} \{P9682, P9690\} \)
  \[ = 2 \cdot \text{min} \{5 \,[\text{Hz}], 10 \,[\text{Hz}]\} = 10 \,[\text{Hz}] \]

Now - considering the case if both functions, SLS and SS1 are parameterized.
In this case, the formula of the resulting frequency tolerance $\Delta Flow$ is given by:

$$\Delta Flow \geq \frac{m}{D} - \Delta F,$$

$$\Delta Flow \geq \frac{20 \text{ [Hz/s]}}{10 \text{ [Hz]}} - 1.5 \text{ [Hz]},$$

$$\Delta Flow \geq 0.5 \text{ [Hz]}$$

4. Delay $\Delta F_{delay}$

Please note that $\Delta Flow$ and $\Delta F_{high}$ can assume both negative values as well as also 0. It is therefore important to compare $\Delta F_{delay}$ with 0 and to determine the maximum value.

The formula is as follows:

$$\Delta F_{delay} = \max [\Delta Flow, \Delta F_{high}, 0]$$

$$= \max [0.5 \text{ [Hz]}, 6 \text{ [Hz]}, 0] = 6 \text{ [Hz]}$$

5. Minimum delay of the braking ramp

The minimum delay of the braking ramp is calculated as follows:

$$P9680 \geq \frac{\Delta F_{delay}}{m},$$

$$P9680 \geq \frac{6 \text{ [Hz]}}{20 \text{ [Hz/s]}},$$

$$P9680 \geq 0.3 \text{ [s]}$$

Parameter P9680 should be parameterized to 300 [ms].

This means that the result of our calculation is as follows:

- The upper tolerance range $P9691 = 16.5 \text{ [Hz]}$
- The minimum delay of the braking ramp $P9680 = 300 \text{ [ms]}$
Appendix and references

4 References

4.1 Reference data

This list is in no way complete and only reflects a selection of suitable references.

Table 4-1

<table>
<thead>
<tr>
<th>Subject area</th>
<th>Title</th>
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<tbody>
<tr>
<td>/1/ SINAMICS G120 Operating Instructions</td>
<td>Operating Instructions: Control Unit CU240S, CU240S DP, CU240S DP-F Software version 2.0</td>
</tr>
<tr>
<td>/2/ SINAMICS G120 parameter list</td>
<td>Parameter Manual: Control Unit CU240S, CU240S DP, CU240S DP-F Software version 2.0</td>
</tr>
<tr>
<td>/3/ Manual</td>
<td>Safety Integrated</td>
</tr>
<tr>
<td>/4/ Getting Started</td>
<td>SIMATIC S7 Distributed Safety</td>
</tr>
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4.2 Internet link data

This list is in no way complete and only reflects a selection of suitable references.

Table 4-2

<table>
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<th>Title</th>
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<tr>
<td>/1/ Web page</td>
<td>Siemens A&amp;D Customer Support</td>
</tr>
<tr>
<td>/2/ Application</td>
<td>SINAMICS G120 - controlled via Profibus Safety functions using Profisafe, Category 3 (EN 954-1) or SIL 2 (IEC 61508)</td>
</tr>
<tr>
<td>/3/ Application</td>
<td>Commissioning SINAMICS G120 Safety-Integrated features with Starter</td>
</tr>
<tr>
<td>/4/ FAQ</td>
<td>Fault F0395 &quot;Acceptance test&quot;</td>
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4.3 History

Table 4-3 History

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<th>Version</th>
<th>Date</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1.0</td>
<td>Januar 2007</td>
<td>First edition</td>
</tr>
<tr>
<td>V1.1</td>
<td>February 2007</td>
<td>Excel spreadsheet (calculation of the limiting values) added</td>
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</tbody>
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