Drive System Application

Engineering braking chopper operation

Application description for SINAMICS G120 and MICROMASTER 440
Warranty, liability and support

The Application Examples are not binding and do not claim to be complete regarding the circuits shown, equipping and any eventuality. The Application Examples do not represent customer-specific solutions. They are only intended to pro vide support for typical applications. You are responsible in ensuring that the de scribed products are correctly used. These Application Examples do not relieve you of the responsibility in safely and professionally using, installing, operating and servicing equipment. When using these Application Examples, you recognize that Siemens cannot be made liable for any damage/claims beyond the liability clause described. We reserve the right to make changes to these Application Examples at any time without prior notice. If there are any deviations between the recommendations provided in these Application Examples and other Siemens publications - e.g. Catalogs - then the contents of the other documents have priority.

Warranty, liability and support

We do not accept any liability for the information contained in this document.

Any claims against us - based on whatever legal reason - resulting from the use of the examples, information, programs, engineering and performance data etc., described in this Application Examples shall be excluded. Such an exclusion shall not apply in the case of mandatory liability, e.g. under the German Product Liability Act ("Produkthaftungsgesetz"), in case of intent, gross negligence, or injury of life, body or health, guarantee for the quality of a product, fraudulent concealment of a deficiency or breach of a condition which goes to the root of the contract ("wesentliche Vertragspflichten"). However, claims arising from a breach of a condition which goes to the root of the contract shall be limited to the foreseeable damage which is intrinsic to the contract, unless caused by intent or gross negligence or based on mandatory liability for injury of life, body or health. The above provisions does not imply a change in the burden of proof to your detriment.

Copyright® 2008 Siemens A&D. It is not permissible to transfer or copy these Application Examples or excerpts of them without first having prior authorization from Siemens A&D in writing.

If you have any recommendations relating to this document then please send them to us at the following e-mail address:

mailto:sdsupport.aud@siemens.com
Aim of the application

For applications where loads must be quickly moved or lowered, or where higher moments of inertia must be braked, then power is regenerated for a specific length of time. The motor then operates as generator and supplies power back into the DC link through the inverter in the drive converter. This causes the DC link voltage to increase. In order to avoid that the DC link voltage increases to an excessive level and an associated fault trip, the MM440 and G120 with PM240 drive units include functions that maintain the DC link voltage within a permissible range. One of these functions is the braking chopper that is integrated as standard in sizes A-F (0.12 – 75 kW). When the motor regenerates, this braking chopper dissipates the braking energy in a braking resistor. Information on the mode of operation of the braking chopper and how to engineer regenerative braking operation is provided in the following description.

Exclusion

This application does not include a description of

- The individual drive inverter
- The STARTER 4.1.1 Tool
- The putting into operation of primary controls

It is assumed that the reader has 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.

Table of Contents

1 Mode of operation of the braking chopper in the MM440 and G120 with PM240
   1.1 Response threshold of the braking chopper .......................................................... 10
   1.2 Load duty cycles and the load capability of the braking chopper ....................... 10

2 Engineering braking operation .............................................................................. 13
   2.1 Maximum braking power .................................................................................... 13
   2.2 Average braking power ..................................................................................... 14
   2.3 Information on columns 1 – 8 of Table 1 and 2: .............................................. 18
   2.4 Example to calculate and check the maximum and average braking power .. 18
      2.4.1 Checking the maximum braking power ....................................................... 20
      2.4.2 Checking the average braking power ......................................................... 20
   2.5 Flow diagram .................................................................................................... 21
   2.6 Braking resistors .............................................................................................. 23
      2.6.1 Connecting the braking resistor .................................................................. 24
      2.6.2 Thermal protection for the braking resistor .............................................. 25
   2.7 Operation together with other types of braking ............................................... 25
   2.8 DC link voltage controller ................................................................................ 25
   2.9 Summary of the frequency converter parameters that are important for regenerative operation ................................................................. 26

3 References ............................................................................................................ 27
   3.1 Reference data .................................................................................................. 27
   3.2 History ............................................................................................................. 27
1 Mode of operation of the braking chopper in the MM440 and G120 with PM240

The braking chopper in the MM440 and SINAMICS G120 with PM 240 essentially comprises an IGBT transistor. If braking operation is activated by the drive converter parameter P1237, then the braking chopper is automatically switched-in at a specific DC link voltage when the motor is regenerating. Above this chopper switch-in threshold \( V_{DC_{Chopper}} \), the DC link is connected to an external braking resistor via the clocked braking transistor (refer to Fig. 1). While the braking transistor is conducting, a power of \( P_{\text{braking resistor max}} = \frac{V_{DC_{Chopper}}^2}{R_{\text{braking resistor}}} \) is dissipated in the braking resistor. The braking chopper is pulsed with a frequency of 2 kHz. This corresponds to a period of 500\( \mu \)s (refer to Fig. 2).

Fig. 1: Principle design of the MM440 and G120 drive converter with braking chopper (at the G120 with PM240 the clamps for the braking resistor are called DCP/R1 and R2).
When the motor is regenerating and the DC link voltage VDC increases, then the braking chopper automatically switches itself on the chopper switch-on threshold $V_{DC, Chopper}$. If the regenerative power presently fed back from the motor into the drive converter DC link is less than the power dissipated in the braking resistor at the chopper switch-on threshold, then the DC link voltage again falls below the chopper switch-on threshold and the braking chopper switches itself off after 2ms. When the DC link voltage increases again, the braking chopper again switches-on and the procedure is repeated (refer to Fig. 3).
If the braking power presently regenerated by the motor is greater than the braking power dissipated in the braking resistor at the chopper threshold, then in spite of the fact that the braking resistor is switched-in, the DC link voltage continues to increase up to a point, where the DC link voltage corresponds to the regenerative braking power. At this value, the DC link voltage stabilizes with a braking power that is still available and the braking chopper is permanently switched-on (refer to Fig.4). This "continuous operation" is only briefly interrupted for approx. 10µs after 500µs (braking chopper is clocked with 2 kHz). The procedure is then appropriately repeated. However, the brief interruption of "continuous operation" for 10µs can be neglected and has not been taken into account in these diagrams. This "continuous operation" can be used for a maximum duration $t_{ON}$. This time depends on the magnitude of the load duty cycle selected in P1237 (refer to Fig. 6).
After the maximum duration $t_{ON}$ has expired for the "continuous operation" the drive converter goes into the load duty cycle set using P1237. This is to thermally protect the connected braking resistor. The load duty cycle is then formed as a result of the ratio between the switch-on time $t_{chopper}$ and the chopper cycle time $t_{chopper}$ ($= 500\mu s$). For a load duty cycle set in P1237 of e.g. 5%, the switch-on time $t_{chopper}$ is therefore 25\mu s (refer to Fig. 5).
Engineering braking chopper operation

Mode of operation of the braking chopper in the MM440 and G120 with PM240

The maximal value for the DC link voltage in braking operation is the drive converter over voltage shutdown threshold \( V_{DC\,\text{max}} \) which is listed in Table 1 and 2 for the particular drive converter. The maximum possible braking power to be dissipated can be calculated from this:

\[
P_{\text{breaking resistor max}} = \frac{V_{DC\,\text{max}}^2}{R_{\text{min}}}
\]

However, this value is a peak value that in practice cannot be fully utilized because of the proximity to the over voltage shutdown (trip) threshold. For safe braking operation with a sufficient safety margin to the over voltage shutdown threshold, then 5% must be subtracted from this maximum braking power \( P_{\text{breaking resistor max}} \).

There is still a transition area available above the chopper switch-on threshold \( V_{DC\,\text{chopper}} \). In this range, the braking chopper linearly increases the on-to-off ratio during the chopper cycle time \( t_{\text{chopper}} (= 500\,\mu\text{s}) \) linearly to a value of 100% depending on the amplitude of the DC link voltage. The DC link voltage range \( \Delta V_{DC} \) for this transition is, for drive units with line supply voltages of:

- 1/3-ph. 200-240V AC equal to 9.8V DC
- 3-ph. 380-480V AC equal to 17.0V DC
- 3-ph. 500-600V AC equal to 21.3V DC
However, this transition range above the chopper switch-on threshold \( V_{DC_{Chopper}} \) is neglected for reasons of simplification.

### 1.1 Response threshold of the braking chopper

The switch-on threshold for the braking chopper \( V_{DC_{Chopper}} \) is automatically determined in the MM440 and G120 with PM240 drive converter each time the power is connected (at each power-up). An appropriate reference value is saved in parameter r1242. The switch-on threshold for the braking chopper \( V_{DC_{Chopper}} \) is in this case 98% of the reference value determined in parameter r1242 \( V_{DC_{Chopper}} = 0.98 \times r1242 \). The automatic determination of the DC link voltage reference value r1242 can also be deselected using parameter P1254. The switch-on threshold for the braking chopper \( V_{DC_{Chopper}} \) then depends on parameter P0210 (line supply voltage):

\[
V_{DC_{Chopper}} = 1.13 \times \sqrt{2} \times P0210
\]

The magnitude of the value for the switch-on threshold of the braking chopper \( V_{DC_{Chopper}} \) does not determine the maximum possible braking power of the drive converter. The reason for this is that for an appropriately high braking power of the motor, the DC link voltage can still continue to increase while the braking chopper is operational.

### 1.2 Load duty cycles and the load capability of the braking chopper

In order to protect the connected braking resistor, a load duty cycle for braking operation must be entered at the MM440 and G120 with PM240 frequency converter using parameter P1237. For the braking resistors assigned to the MM440 frequency converter in Catalog DA51.2 and for G120 with PM240 frequency converter in Catalog DA11.1, a permissible load duty cycle is specified as 5%. The braking chopper integrated in the MM440 and G120 frequency converter can have a continuous load of the maximum braking power \( P_{Brakingresistor_{max}} = \frac{V_{DC_{max}}^2}{R_{min}} \) (refer to table 1 and 2). However, in this case it is important that the frequency converter can handle this level of power with its inverter (overload capability of the frequency converter) – and the connected braking resistor is designed for this power rating. If the maximum frequency converter power (overload capability, 200% for 3s) is less than the maximum braking power of the integrated braking chopper \( P_{Brakingresistor_{max}} \), then this power is the maximum braking power that can be achieved.
When selecting a specific load duty cycle for braking operation in parameter P1237 (e.g. 5% when using the MM440 or G120 braking resistors), then for a appropriately high braking power, the braking chopper can brake for the maximal duration $t_{ON}$ with the maximum braking power $P_{\text{braking resistor max}}$. After this time expires, the selected load duty cycle (e.g. 5%) us forcibly selected by the switch-on to switch-off ratio during the chopper cycle time $t_{chopper}$ (= 500µs) (refer to Fig. 5). If the actual braking power is then higher than that corresponding to the selected load duty cycle, then the DC link over voltage shutdown point (trip point) with a fault message. In this case, a higher load duty cycle should be set in parameter P1237 using a suitable braking resistor.

For a single braking operation, the drive can brake with the maximum braking power $P_{\text{braking resistor max}}$ for the maximum duration $t_{ON}$ followed by the continuous power $P_{\text{braking resistor average}}$. For cyclic operations, after braking with the maximum braking power $P_{\text{braking resistor max}}$ for the maximum duration $t_{ON}$, there must be a no-load time $t_{OFF}$ before the maximum braking power $P_{\text{braking resistor max}}$ can be used again (refer to Fig. 6).

Depending on the setting of the load duty cycle in parameter P1237, different values for the maximum duration $t_{ON}$ with maximum braking power $P_{\text{braking resistor max}}$, no-load interval time $t_{OFF}$ and the load duty cycle duration $t_{cycle\ chopper}$ are obtained. The appropriate values are shown in Fig. 6 that must be used as basis when engineering braking operation.

![Diagram](image)

**Fig. 6:** Switch-on and no-load interval time ($t_{ON}$ and $t_{OFF}$) as well as the load duty cycle duration $t_{cycle\ chopper}$ as a function of parameter P1237; $t_{ON}$, $t_{OFF}$ and $t_{cycle\ chopper}$ in (s).

<table>
<thead>
<tr>
<th>P1237</th>
<th>$t_{ON}$</th>
<th>$t_{OFF}$</th>
<th>$t_{cycle\ chopper}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 %</td>
<td>12.0</td>
<td>228.0</td>
<td>240.0</td>
</tr>
<tr>
<td>10 %</td>
<td>12.6</td>
<td>114.0</td>
<td>126.6</td>
</tr>
<tr>
<td>20 %</td>
<td>14.2</td>
<td>57.0</td>
<td>71.2</td>
</tr>
<tr>
<td>50 %</td>
<td>22.8</td>
<td>22.8</td>
<td>45.6</td>
</tr>
<tr>
<td>100 %</td>
<td>Infinite</td>
<td>0</td>
<td>Infinite</td>
</tr>
</tbody>
</table>
The above mentioned braking profile only defines the maximum load capability of the braking chopper as a function of the load duty cycle set in parameter P1237 to protect the connected braking resistor. However, in practice and depending on the application, the timing/sequence of the braking operation can differ. A check as to whether this application-specific braking profile can be achieved with the frequency converter is described in the following text.
2 Engineering braking operation

When engineering the drive for braking operation, to start, the maximum and average braking power for the application must be determined. In this case, for example, the SIZER program from version 2.1 onwards can be used. However, it should be noted that the SIZER program uses a load duty cycle duration of 90s as basis when calculating the average braking power for the application. If the load duty cycle duration, which is obtained from the selected load duty cycle with parameter P1237, is greater than 90s, then the average braking power can be taken from the SIZER program. For a selected load duty cycle of 5% \( (t_{cyclechopper} = 240s) \) and 10% \( (t_{cyclechopper} = 126.6s) \) this is guaranteed. For a load duty cycle that is selected to be \( \geq 20\% \) in parameter P1237, the load duty cycle duration \( t_{cyclechopper} \) is less than 90s and this means that the value from the SIZER program cannot be used to check the average braking power (refer to Fig. 6).

2.1 Maximum braking power

In this case a check must be made as to whether the maximum braking power occurring in the application \( P_{app,\max} \) can be dissipated in the braking resistor. In this case, the following condition must be fulfilled:

\[
P_{Brakingapp,\max} \leq P_{Brakingresistor,\max}
\]

\( P_{Brakingapp,\max} \):
Maximum peak braking power that occurs for the application

\( P_{Brakingresistor,\max} \):
Maximum possible peak braking power of the braking chopper with the selected braking resistor (refer to Table 1 and 2)

The maximum possible peak braking power of the braking chopper \( P_{Brakingresistor,\max} \) depends on the resistor value of the connected braking resistor. It is calculated as follows:

\[
P_{Brakingresistor,\max} = \frac{VDC_{\max}^2}{R_{Brakingresistor}}
\]
As has already been mentioned, this value is a peak value that cannot be fully utilized in practice because of the proximity to the over voltage shutdown threshold. For safe braking operation with a sufficient safety margin to the over voltage shutdown threshold, 5% must be subtracted from this maximum braking power $P_{\text{Braking resistor max}}$.

A minimum resistor value $R_{\text{min}}$ must be maintained in order to protect the chopper transistor (refer to Table 1 and 2). The peak braking power of the braking chopper $P_{\text{Braking resistor max}}$ that can be achieved with this minimum resistor value is therefore a maximum value.

A prerequisite when utilizing the maximum peak braking power of the braking chopper is that the maximum frequency converter output current (overload current) is not reached when the motor is regenerating.

The overload capability of the MM440 and G120 with PM240 frequency converter in sizes A-F is as follows:

For MM440
- 2.0 x frequency converter rated output current for 3s every 300s
- 1.5 x frequency converter rated output current for 60s every 300s

For G120 with PM240
- 2.0 x frequency converter rated output current for 3s every 300s
- 1.5 x frequency converter rated output current for 57s every 300s

The maximum motor current occurring for the particular application can e.g. be calculated using the SIZER program.

### 2.2 Average braking power

The average braking power is predominantly checked to thermally protect the connected braking resistor. The braking resistors assigned to the MM440 frequency converter in Catalog DA52.1 and for G120 with PM240 in Catalog DA11.1 have an average braking power of approx. 5% of the maximum braking power (refer to Table 1 and 2). If this average braking power of the MM440/G120 braking resistor is too low for the application, then when 4x MM440/G120 braking resistors are used, the available continuous braking power can be increased to 20% of the maximum braking power. To realize this, the braking resistors are connected as shown in Fig. 7.
As an alternative, other braking resistors can be used e.g. from the MASTERDRIVES product range. When the braking resistors are appropriately dimensioned, the average braking power can be increased up to 100% of the maximum braking power. However in this case the prerequisite up to 100% of the frequency converter rated output current is not exceeded. The load duty cycles, shown in Fig. 6, can be selected using parameter P1237. For a load duty cycle of e.g. 5%, this means that the average permissible braking power \( P_{\text{braking resistor average}} \) is approx. 5% of the maximum braking power. In operation, the frequency converter monitors the braking resistor load and limits this to the selected value, when the load duty cycle is set – and therefore the average permissible braking power in P1237, then this also modifies the load duty cycle duration \( t_{\text{cycle chopper}} \) of the braking chopper (refer to Fig. 6). If the load duty cycle of the application \( t_{\text{cycle app}} \) is less than the load duty cycle duration \( t_{\text{cycle chopper}} \) of the braking chopper, then the average braking power of the application \( P_{\text{braking app average}} \) can be directly compared to the average permissible braking power \( P_{\text{braking resistor average}} \):

\[
P_{\text{braking app average}} \leq P_{\text{braking resistor average}}
\]

For a longer load duty cycle duration of the application \( t_{\text{cycle app}} \) \((t_{\text{cycle app}} > t_{\text{cycle chopper}})\), a time slice with a duration of \( t_{\text{cycle chopper}} \) must be selected from the application load duty cycle where the average value of the braking power \( P_{\text{braking app average}} \) is the highest. This value for \( P_{\text{braking app average}} \) is then used to make the check.
## Engineering braking chopper operation

**Order No.** 6SE6400-

**ID-No:** 22101908

**Version 1.2** Issue March 2008 16/27

**Copyright © Siemens AG 2008 All rights reserved**

**PDF_Engineering_braking_chopper_operation_V1_2_en.doc**

---

**Table 1: Technical data for braking chopper operation using the MM440 and G120 with PM240 for Sizes A-F (power ratings from 0.12 to 75kW)**

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MM440 braking resistor</strong></td>
<td><strong>Frequency converter frame size</strong></td>
<td><strong>Frequency converter input voltage (V)</strong></td>
<td><strong>Frequency converter power rating CT (kW)</strong></td>
<td><strong>Continuous braking power (W)</strong></td>
<td><strong>Maximum braking power (W)</strong></td>
<td><strong>MM440 braking resistance value Rmin (Ω)</strong></td>
<td><strong>Maximum DC link voltage VDC max (V)</strong></td>
</tr>
<tr>
<td>4BC05-0AA0</td>
<td>A</td>
<td>200 - 240</td>
<td>0.12 - 0.75</td>
<td>50</td>
<td>980</td>
<td>180</td>
<td>420</td>
</tr>
<tr>
<td>4BC11-2BA0</td>
<td>B</td>
<td>200 – 240</td>
<td>1.1 - 2.2</td>
<td>120</td>
<td>2600</td>
<td>68</td>
<td>420</td>
</tr>
<tr>
<td>4BC12-5CA0</td>
<td>C</td>
<td>200 – 240</td>
<td>3.0</td>
<td>250</td>
<td>4500</td>
<td>39</td>
<td>420</td>
</tr>
<tr>
<td>4BC13-0CA0</td>
<td>C</td>
<td>200 – 240</td>
<td>4.0 - 5.5</td>
<td>300</td>
<td>6500</td>
<td>27</td>
<td>420</td>
</tr>
<tr>
<td>4BC18-0DA0</td>
<td>D</td>
<td>200 – 240</td>
<td>7.5 - 15.0</td>
<td>800</td>
<td>16800</td>
<td>10</td>
<td>410</td>
</tr>
<tr>
<td>4BC21-2EA0</td>
<td>E</td>
<td>200 – 240</td>
<td>18.5 - 22.0</td>
<td>1200</td>
<td>24700</td>
<td>6.8</td>
<td>410</td>
</tr>
<tr>
<td>4BC22-5FA0</td>
<td>F</td>
<td>200 - 240</td>
<td>30.0 - 45.0</td>
<td>2500</td>
<td>51000</td>
<td>3.3</td>
<td>410</td>
</tr>
<tr>
<td>4BD11-0AA0</td>
<td>A</td>
<td>380 - 480</td>
<td>0.37 - 1.5</td>
<td>100</td>
<td>1800</td>
<td>390</td>
<td>840</td>
</tr>
<tr>
<td>4BD12-0BA0</td>
<td>B</td>
<td>380 – 480</td>
<td>2.2 - 4.0</td>
<td>200</td>
<td>4400</td>
<td>160</td>
<td>840</td>
</tr>
<tr>
<td>4BD16-5CA0</td>
<td>C</td>
<td>380 – 480</td>
<td>5.5 - 11.0</td>
<td>650</td>
<td>12600</td>
<td>56</td>
<td>840</td>
</tr>
<tr>
<td>4BD21-2DA0</td>
<td>D</td>
<td>380 – 480</td>
<td>15.0 - 22.0</td>
<td>1200</td>
<td>24900</td>
<td>27</td>
<td>820</td>
</tr>
<tr>
<td>4BD22-2EA0</td>
<td>E</td>
<td>380 – 480</td>
<td>30.0 - 37.0</td>
<td>2200</td>
<td>44800</td>
<td>15</td>
<td>820</td>
</tr>
<tr>
<td>4BD24-0FA0</td>
<td>F</td>
<td>380 – 480</td>
<td>45.0 - 75.0</td>
<td>4000</td>
<td>82000</td>
<td>8.2</td>
<td>820</td>
</tr>
<tr>
<td>4BE14-5CA0</td>
<td>C</td>
<td>500 - 600</td>
<td>0.75 - 5.5</td>
<td>450</td>
<td>8600</td>
<td>120</td>
<td>1020</td>
</tr>
<tr>
<td>4BE16-5CA0</td>
<td>C</td>
<td>500 – 600</td>
<td>7.5 - 11.0</td>
<td>650</td>
<td>12700</td>
<td>82</td>
<td>1020</td>
</tr>
<tr>
<td>4BE21-3DA0</td>
<td>D</td>
<td>500 – 600</td>
<td>15.0 - 22.0</td>
<td>1300</td>
<td>26700</td>
<td>39</td>
<td>1020</td>
</tr>
<tr>
<td>4BE21-9EA0</td>
<td>E</td>
<td>500 – 600</td>
<td>30.0 - 37.0</td>
<td>1900</td>
<td>38500</td>
<td>27</td>
<td>1020</td>
</tr>
<tr>
<td>4BE24-2FA0</td>
<td>F</td>
<td>500 - 600</td>
<td>45.0 - 75.0</td>
<td>4200</td>
<td>86700</td>
<td>12</td>
<td>1020</td>
</tr>
</tbody>
</table>

---

**MM440 braking resistor**

Order No. 6SE6400-

---

**Frequency converter frame size**

---

**Frequency converter input voltage (V)**

---

**Frequency converter power rating CT (kW)**

---

**Continuous braking power (W)**

---

**Maximum braking power (W)**

---

**MM440 braking resistance value Rmin (Ω)**

---

**Maximum DC link voltage VDC max (V)**

---
For frame size B there is a special braking resistor for SINAMICS G120 with the following data:

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>MM440 braking resistor</td>
<td>Frequency converter input voltage</td>
<td>Frequency converter power rating</td>
<td>Continuous braking power</td>
<td>Maximum braking power</td>
<td>MM440 braking resistance value / Rmin</td>
<td>Maximum DC link voltage VDC max</td>
<td></td>
</tr>
<tr>
<td>Order No. 6SL3201-</td>
<td>(V)</td>
<td>(kW)</td>
<td>(W)</td>
<td>(W)</td>
<td>(Ω)</td>
<td>(V)</td>
<td></td>
</tr>
<tr>
<td>0BE12-0AA0</td>
<td>B</td>
<td>380 - 480</td>
<td>2.2 – 4.0</td>
<td>200</td>
<td>4000</td>
<td>180</td>
<td>840</td>
</tr>
</tbody>
</table>

Table 2: Technical data for braking chopper operating using the G120 special for frame size B.
2.3 Information on columns 1 – 8 of Table 1 and 2:

Column:

1) Order number of the assigned MM440/G120 braking resistor
2) Applicable frame size of the frequency converter
3) Frequency converter input voltage
4) Power range of the frequency converter for the particular frame size
5) Continuous braking power $P_{\text{brakingresistor,cont}}$ of the assigned MM440/G120 braking resistor with a load cycle duration of 240s.
6) Maximum achievable peak braking power $P_{\text{brakingresistor,peak}}$ of the integrated braking chopper. However, this peak value is only reached if the DC link voltage, during braking increases up to the shutdown threshold (trip threshold) of the frequency converter due to a high braking power that has to be dissipated. In practice, the value specified in column 6 cannot be fully utilized because of the proximity to the over voltage shutdown threshold. In order to achieve safe braking operation with sufficient safety margin to the over voltage shutdown threshold, then 5% must still be subtracted from the maximum braking power $P_{\text{brakingresistor,peak}}$. The maximum peak braking power of the integrated braking chopper is limited by the max. frequency converter power (overload capability, 200% for 3s and 150% for 60s for MM440, overload capability for G120, 200% for 3s and 150% for 57s). The integrated braking chopper can also be continually loaded with the specified peak braking power. However, this value is limited from the maximum possible continuous power of the frequency converter. Further, a suitable braking resistor must be used.
7) Value of the resistance of the assigned MM440/G120 braking resistor. This is also the minimum resistance value of an external resistor that can be connected.
8) Maximum DC link voltage that can be reached until the frequency converter is shutdown due to an over voltage condition.

2.4 Example to calculate and check the maximum and average braking power

A grinding disk drive is to be braked from a speed of 2900 RPM down to standstill (refer to Fig. 8); in this case the effect of friction is neglected. The other application data include:

Frequency converter rated power: $P_{\text{cont}} = 5.5kW$
Max. braking power of the braking chopper in the freq. converter: 

\[ P_{\text{Brakingresistor max}} = 12.6kW \]

Motor rated power: 

\[ P_{\text{motorN}} = 5.5kW \]

Motor efficiency: 

\[ \eta_{\text{motor}} = 0.865 \]

Motor rated speed: 

\[ n_{\text{motorN}} = 2925RPM \]

Motor moment of inertia: 

\[ J_{\text{motor}} = 0.015kgm^2 \]

Moment of inertia of the grinding wheel (referred to the motor): 

\[ J_{\text{grind}} = 0.4kgm^2 \]

Max. motor speed for the application: 

\[ n_{\text{max}} = 2900RPM \]

Grinding disk braking time: 

\[ t_{\text{Brakeappl}} = 5s \]

Load duty cycle duration of the application: 

\[ t_{\text{cycleappl}} = 15s \]

---

**Fig. 8: Characteristic of the braking torque and the braking power for the application example**
2.4.1 Checking the maximum braking power

Braking torque: 
\[ M_{\text{Brakeappl}} = \frac{(J_{\text{motor}} + J_{\text{grind}}) \cdot n_{\text{max}}}{9.55 \cdot t_{\text{Brakeappl}}} \]

\[ M_{\text{Brakeappl}} = \frac{(0.015\text{kgm}^2 + 0.4\text{kgm}^2) \cdot 2900\text{RPM}}{9.55 \cdot 5\text{s}} = 25.2\text{Nm} \]

Maximum braking power: 
\[ P_{\text{Brakeappl max}} = \frac{M_{\text{Brakeappl}} \cdot n_{\text{max}}}{9.55} \cdot \eta_{\text{motor}} \]

\[ P_{\text{Brakeappl max}} = \frac{25.2\text{Nm} \cdot 2900\text{RPM}}{9.55} \cdot 0.865 = 6.6\text{kW} \]

This means that the condition \( P_{\text{Brakeappl max}} (6.6\text{kW}) \leq P_{\text{Braking resistor max}} (12.6\text{kW}) \) is fulfilled.

2.4.2 Checking the average braking power

Average braking power in the application load duty cycle 15s:
\[ P_{\text{app average}} = \frac{1}{2} \cdot P_{\text{app max}} \cdot \frac{t_{\text{Brakeappl}}}{t_{\text{cyc appl}}} \]

\[ P_{\text{app average}} = \frac{1}{2} \cdot 6.6\text{kW} \cdot \frac{5\text{s}}{15\text{s}} = 1.1\text{kW} \]

A suitable braking resistor must now be selected with the average braking power of \( P_{\text{Brakeappl average}} = 1.1\text{kW} \) and the load duty cycle duration of the application \( t_{\text{cyc appl}} = 15\text{s} \). The braking resistor assigned in Catalog DA51.2 and Catalog DA11.1 with an average permissible braking power \( P_{\text{Braking resistor average}} = 0.65\text{kW} \) is too small for this application. For the application example, 4x MM440/G120 braking resistors can be used that must be connected-up as shown in Fig. 7. The permissible average braking power \( P_{\text{Braking resistor average}} \) is then \( 4 \cdot 0.65\text{kW} = 2.6\text{kW} \) and is therefore sufficient. The load duty cycle at the frequency converter must be set to “3” (20%) in the MM440/G120 parameter P1237; the load duty cycle duration of the braking chopper \( t_{\text{cycle chopper}} \) thus obtained is with 71.2s (refer to Fig. 6) greater than the load duty cycle duration of the application \( t_{\text{cyc appl}} = 15\text{s} \).

The conditions:
\[ t_{\text{cyc appl}}(15\text{s}) \leq t_{\text{cycle chopper}}(71.2\text{s}) \]
\[ P_{\text{Brakeaverage}} (1.1kW) \leq P_{\text{Brakingresistoraverage}} (2.6kW) \]

are therefore fulfilled.

As an alternative, another individual braking resistor can be used that can dissipate the average braking power. A suitable braking resistor from the MASTERDRIVES product range is the resistor with Order No. 6SE7018-0ES87-2DC0. This has a permissible average braking power of 1.24kW, a resistor value of 80Ω and a cycle time of 90s. A subsequent calculation is required due to the higher resistor value with respect to the MM440/G120 braking resistor (56Ω). The maximum peak braking power that can be dissipated in the 80Ω resistor is given by:

\[
P_{\text{Brakingresistor max}} = \frac{V_{\text{DC max}}^2}{R_{\text{Brakingresistor}}} = \frac{840^2 \cdot 8^2}{80\Omega} = 8.82kW
\]

This value is higher than the max. braking power of the application (6.6kW) and is therefore adequate.

In order to be able to dissipate the average braking power of the application \( P_{\text{Brakeaverage}} = 1.1kW \), a load duty cycle duration of 20% should be set in parameter P1237. The frequency converter load duty cycle monitoring limits the average braking power to 20% of \( P_{\text{Brakingresistor max}} \) (20% of 8.82kW) = 1.76kW; however this is not reached in this particular application. The cycle time (90s) of the braking resistor is greater than the load duty cycle duration of the braking chopper \( t_{\text{chop}} \) (71.2s). This means that it is not overloaded for this particular load duty cycle.

Information:

- For this application, it is not possible to connect 2x MM440/G120 braking resistors in series as the total (summed) resistor of \( 2 \times 56\Omega = 112\Omega \) would result in a maximum peak braking power of 6.3kW — that is too small.

- The maximum braking power \( P_{\text{Brakingresistor max}} \) from Table 1 and 2 is not achieved for the application example so that sufficient safety margin to the over voltage shutdown threshold is guaranteed.

2.5 Flow diagram

The following flow diagram (Fig. 9) clearly shows the procedure on how the braking powers are checked.
Fig. 9: Flow diagram to check the braking powers

1. The maximum occurring braking power for the application $P_{\text{Brake appl max}}$ is calculated.
2. The average braking power for the application $P_{\text{Brake appl average}}$ is calculated.
3. The peak braking power of the braking chopper $P_{\text{Braking resistor max}}$ is determined from Table 1 and 2.
4. The permissible average braking power of the braking resistor $P_{\text{Braking resistor average}}$ is determined; for the MM440/G120 braking resistor, values from Table 1 and 2.

- If $P_{\text{Brake appl max}} < P_{\text{Braking resistor max}}$
  - Use the higher values $P_{\text{Braking resistor max}}$ and $P_{\text{Braking resistor average}}$ of the higher rating frequency converter.

- Is it possible to enter modified application data, e.g., a longer ramp-down time?
  - Is it possible to use a larger MM440/G120 frequency converter with a higher maximum braking power?

- If $P_{\text{Brake appl average}} < P_{\text{Braking resistor average}}$
  - The selected MM440/G120 frequency converter and braking resistor can be used.

- The selected braking resistor cannot be used.
  - Remedy:
    - Use 4x MM440/G120 braking resistors, load duty cycle 20%.
    - Use another suitable braking resistor (e.g., from the MASTERDRIVES product range), load duty cycle up to 100%.

In so doing the following values should be maintained:
- $R_{\text{Braking resistor}} \geq R_{\text{Min}}$
- $P_{\text{Brake appl max}} \leq P_{\text{Braking resistor max}}$
- $P_{\text{Brake appl average}} \leq P_{\text{Braking resistor average}}$

End
2.6 Braking resistors

The MM440/G120 braking resistors, assigned in Catalog DA51.2 and Catalog DA11.1 are predominantly used as the braking resistors (refer to Table 1 and 2). The average braking power of the braking resistors $P_{\text{Braking resistor average}}$ is approx. 5% of the maximum braking power $P_{\text{Braking resistor max}}$. In order to increase $P_{\text{Braking resistor average}}$, 4x braking resistors according to Fig. 7 can be used. In this case, 400% of the average braking power can be reached; the load duty cycle (parameter P1237) can be set to 20%. However, the maximum braking power $P_{\text{Braking resistor max}}$ does not change as the resulting value of the resistance at $R_{\text{min}}$ remains the same. As an alternative, other braking resistors with a higher average braking power $P_{\text{Braking resistor average}}$ (e.g. from the MASTERDRIVES product range) can be used. In this case the following conditions must be maintained:

- Required voltage strength of the braking resistors:
  - 1/3-ph. 200V – 240V AC devices: 450V DC
  - 3-ph. 380V – 480V AC devices: 900V DC
  - 3-ph. 500V – 600V AC devices: 1100V DC

- $R_{\text{Braking resistor}} \geq R_{\text{min}}$ (values for $R_{\text{min}}$ refer to Table 1 and 2)

- $P_{\text{Brakeappl max}} \leq P_{\text{Braking resistor max}}$

The maximum peak braking power that can be achieved with the braking resistor:

$$P_{\text{Braking resistor max}} = \frac{V_{\text{DC max}}^2}{R_{\text{Braking resistor}}}$$

(minus 5% due to the safety margin to the over voltage shutdown limit)

- $P_{\text{Braking resistor average}} \leq P_{\text{Braking resistor average}}$

(the load duty cycle of the resistor must in this case be greater than the load duty cycle duration of the braking chopper $t_{\text{cyclechopper}}$)
The following applies:

- \( R_{braking resistor} \): Resistance of the external braking resistor
- \( R_{\text{min}} \): Lowest possible value of resistance - corresponds to the resistance of the assigned MM440/G120 braking resistor
- \( P_{\text{brake, average}} \): Average braking power of the application
- \( P_{\text{braking resistor, average}} \): Continuous power of the braking resistor
- \( P_{\text{brake, max}} \): Peak braking power of the application
- \( P_{\text{braking resistor, max}} \): Peak braking power of the braking resistor
- \( VDC_{\text{max}} \): Maximum DC link voltage (refer to Table 1 and 2)

The Internet addresses of potential braking resistor manufactures are listed in the following. The information provided by the suppliers when using braking resistors must be carefully observed.

- REO, D-42657 Solingen [http://www.reo.de/product_list/231](http://www.reo.de/product_list/231)
- GINO, D-53117 Bonn [http://www.gino.de/produkte/bremswiderstaende](http://www.gino.de/produkte/bremswiderstaende)
- Koch, D-76698 Ubstadt [http://www.koch-mk.de](http://www.koch-mk.de)

### 2.6.1 Connecting the braking resistor

The braking resistor is connected at terminals B+/DC+ and B- of the frequency converter MM440 (at the SINAMICS G120 with PM240 the clamps are called DCP/R1 and R2). In order to avoid EMC noise emission, the connecting cable must be shielded and the shield must be connected at both ends. The EMC Design Guidelines must be carefully observed, including the spatial separation of power and signal cables. Additional information and instructions for an EMC-correct design are included in the “EMC Design Guidelines for MICROMASTER”. The maximum distance between the MM440 frequency converter and braking resistor (Sizes A-F) is 25m (shielded). For the SINAMICS G120 with PM240 the maximum distance between frequency converter and braking resistor is 15m.
2.6.2 Thermal protection for the braking resistor

The connected MM440/G120 braking resistor is thermally monitored using the load duty cycle monitoring of the frequency converter. To realize this, parameter P1237 should be set to “1” (5% load duty cycle) or for 4x connected MM440/G120 braking resistors – as shown in Fig. 7 – the value “3” (20% load duty cycle). When third-party braking resistors are used, under certain circumstance, the permissible average braking power of the resistor doesn’t precisely correspond to the load duty cycle selected in P1237. By evaluating a thermo switch, provided in the braking resistor, this can however be thermally protected.

2.7 Operation together with other types of braking

Regenerative braking using braking resistors is the most effective and most accurate braking technique for the MM440 and G120 with PM240 drive units. When the resistor braking is activated using parameter P1237, it is not permissible that compound braking (P1236) is used. The compound braking switches itself in, dependent on the magnitude of the DC link voltage, at the same switch-on threshold as for the braking chopper. If both braking types were to be simultaneously used, then this would cause the frequency converter to malfunction. When required, DC braking (parameter P1230 – P1234) can be switched-in if, for example, a holding torque should be provided when the motor is at a standstill.

2.8 DC link voltage controller

If the braking chopper of the frequency converter is activated, than the $V_{DC\ max}$ controller of the frequency converter (parameter P1240) must be deactivated as both functions mutually influence one another and can cause the frequency converter to malfunction. The $V_{DC\ min}$ controller of the frequency converter can however be activated (kinetic buffering, that can also be set using parameter P1240).
2.9 Summary of the frequency converter parameters that are important for regenerative operation

<table>
<thead>
<tr>
<th>MM440 and G120 parameters</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1121 Ramp-down time: Longer ramp-down times result in a lower maximum braking power. The maximum braking power occurs at the beginning of the ramp down.</td>
<td></td>
</tr>
<tr>
<td>P1132 Ramp-down initial rounding time: An ramp-down initial rounding-time reduces the maximum braking power</td>
<td></td>
</tr>
<tr>
<td>P1230-P1234 DC braking: This can, for example, be activated to lock the motor after regenerative braking down to zero speed (resistor braking).</td>
<td></td>
</tr>
<tr>
<td>P1236 Compound braking: This may not be simultaneously activated with the resistor braking due to the same response thresholds.</td>
<td></td>
</tr>
<tr>
<td>P1237 Resistor braking: This is activated by setting a value greater than &quot;0&quot;. This enters the load duty cycle for the braking chopper.</td>
<td></td>
</tr>
<tr>
<td>P1240 VDC controller: When resistor braking is activated, this may not be set to the value “1” or “3”.</td>
<td></td>
</tr>
<tr>
<td>r1242 Switch-on signal level VDC max controller: The braking chopper switches-in at VDC chopper = 0.98 • r1242. The value for r1242 is newly sensed each time that the frequency converter is connected to the line supply.</td>
<td></td>
</tr>
<tr>
<td>P1254 Automatically sensing the VDC max switch-in level: This function is deactivated for the setting &quot;0&quot;. Setting then with P210 (line supply voltage).</td>
<td></td>
</tr>
</tbody>
</table>
3 References

3.1 Reference data

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

Table 3-1

<table>
<thead>
<tr>
<th>Subject area</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/1</td>
<td>Catalog D11.1 SINAMICS G110/G120 Inverter chassis units</td>
</tr>
<tr>
<td></td>
<td>SINAMICS G120D Distributed frequency inverters</td>
</tr>
<tr>
<td>2/1</td>
<td>Catalog DA51.2 Frequency inverters MICROMASTER 420/430/440</td>
</tr>
<tr>
<td>3/3</td>
<td>Manuals SINAMICS G120</td>
</tr>
<tr>
<td>4/4</td>
<td>Manuals MICROMASTER 4</td>
</tr>
<tr>
<td>5/5</td>
<td>Manuals MICROMASTER 4: EMC Design Guideline</td>
</tr>
<tr>
<td>6/6</td>
<td>Update Intranet Release for sale, extended power ratings for</td>
</tr>
<tr>
<td></td>
<td>SINAMICS PM240 Framesize F 110 kW and 132 kW</td>
</tr>
</tbody>
</table>

3.2 History

Table 3-2 History

<table>
<thead>
<tr>
<th>Version</th>
<th>Datum</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1.0</td>
<td>March 2004</td>
<td>First edition</td>
</tr>
<tr>
<td>V1.1</td>
<td>June 2006</td>
<td></td>
</tr>
<tr>
<td>V1.2</td>
<td>March 2008</td>
<td>Text revised, insert G120 / PM240 data</td>
</tr>
</tbody>
</table>