Application

Edition 05/04

micromaster

SIEMENS

MICROMASTER 440
Engineering braking chopper operation

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Revisions/author

Version	**Date/change**	**Author**
1.0	25.05.04 / First edition	Haßold

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1 Introduction

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 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 – 75kW). 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 application description.

2 Mode of operation of the braking chopper in the MM440

The braking chopper in the MM440 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 $P_{braking\ resistor\ max} = V_{DC\ chopper}{}^2 / R_{braking\ resistor}$ is dissipated in the braking resistor. The braking chopper is pulsed with a frequency of 2kHz. This corresponds to a period of 500µs (refer to Fig. 2).

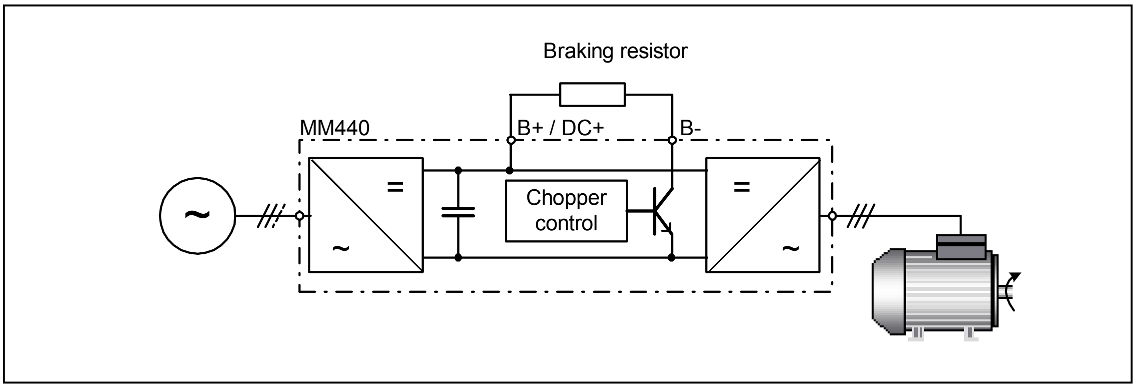


Fig. 1: Principle design of the MM440 drive converter with braking chopper

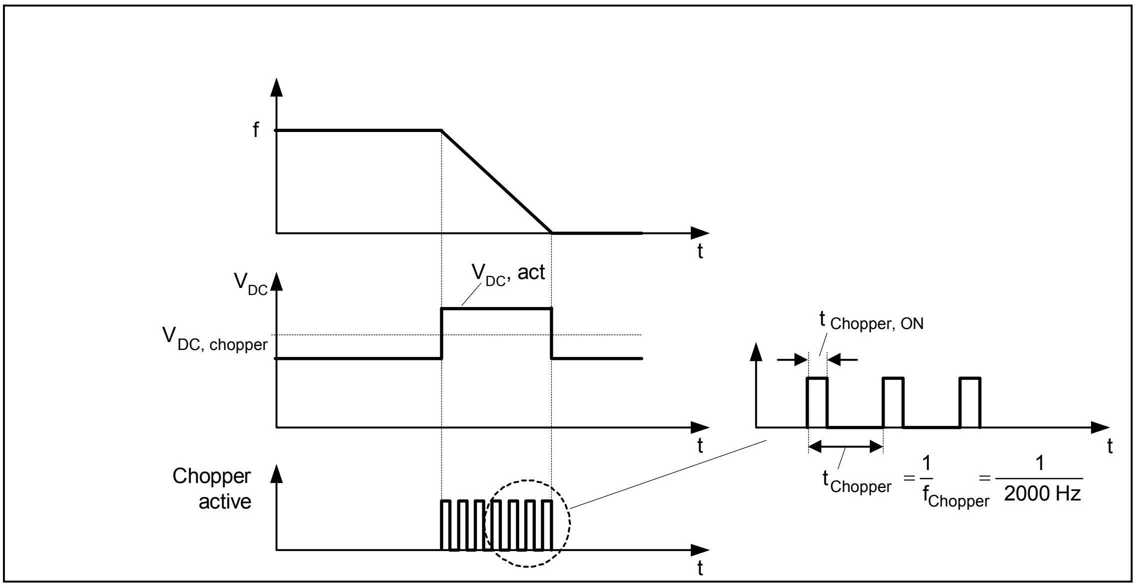


Fig. 2: Clocking the braking chopper for regenerative operation with the selected load duty cycle

When the motor is regenerating and the DC link voltage V_{DC} increases, then the braking chopper automatically switches itself on at 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).

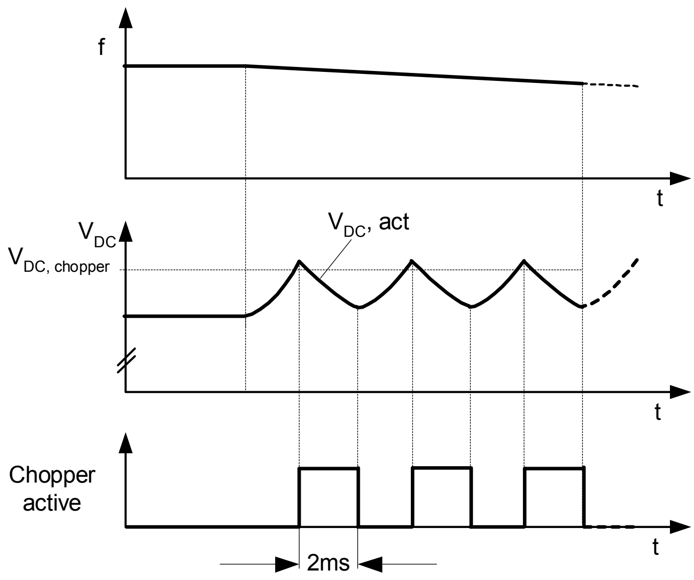


Fig. 3: Braking chopper operation for low regenerative power

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 2kHz). 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).

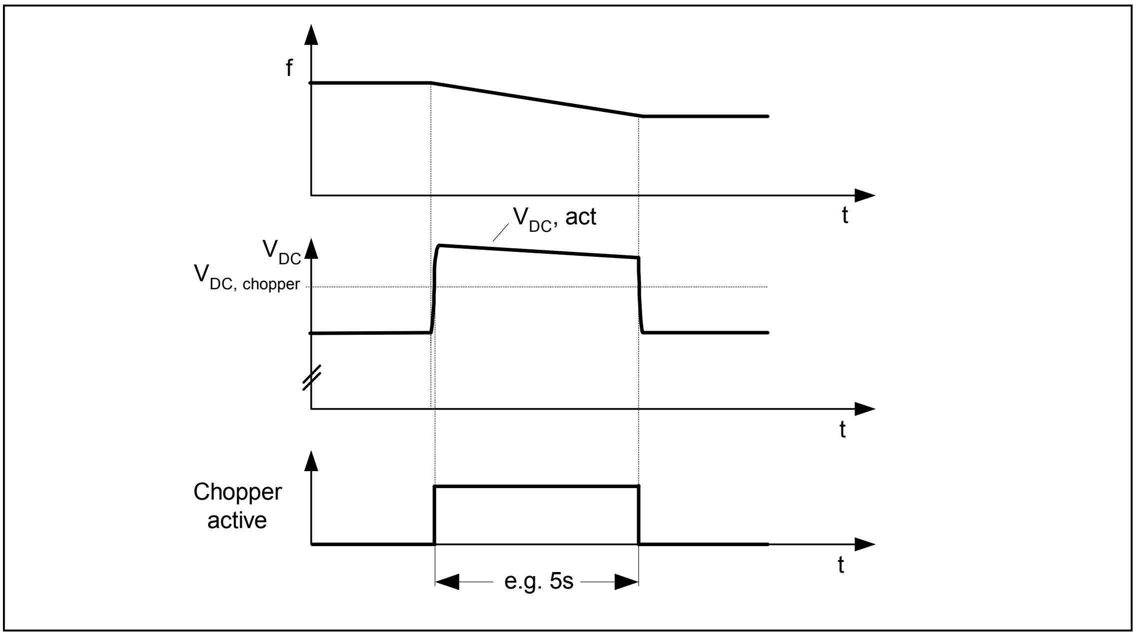


Fig. 4: Braking chopper operation for higher regenerative power - e.g. due to higher load moments of inertia

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 $t_{chopper\ on}$ and the chopper cycle time $t_{chopper}$ (=500µs). For a load duty cycle set in P1237 of
e.g. 5%, the switch-on time $t_{chopper\ on}$ is therefore 25µs (refer to Fig. 5).

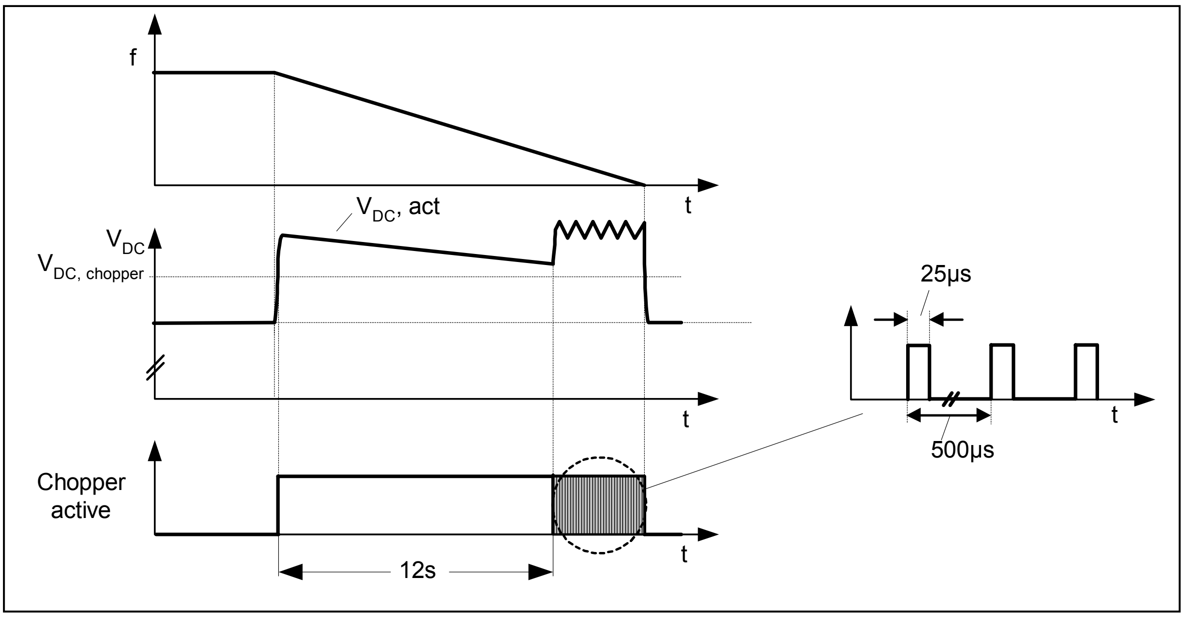


Fig. 5: Example for continuous operation with a subsequent load duty cycle of 5%

The max. value for the DC link voltage in braking operation is the drive converter overvoltage shutdown threshold $V_{DC\text{-}max}$ which is listed in Table 1 for the particular drive converter. The maximum possible braking power to be dissipated can be calculated from this:

$$\mathbf{P_{braking\ resistor\ max} = V_{DC\text{-}max}{}^2 / R_{min}}$$

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

There is still a transition area available above the chopper switch-on threshold $V_{DC\ chopper}$. In this range, the braking chopper lineally increases the on-to-off ratio during the chopper cycle time $t_{chopper}$ (=500µs) linearly to a value of 100% depending on the amplitude of the DC link voltage. The DC link voltage range ΔV_{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.

2.1 Response threshold of the braking chopper

The switch-on threshold for the braking chopper $V_{DC\ chopper}$ is automatically determined in the MM440 drive converter each time that 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 ($V_{DC\ chopper} = 0.98 \bullet r1242$). The automatic determination of the DC link voltage reference value r1242 can also be de-selected using parameter P1254. The switch-on threshold for the braking chopper $V_{DC\ chopper}$ then depends on parameter P0210 (line supply voltage):

$$V_{DC\ chopper} = 1.13 \bullet \sqrt{2} \bullet P0210.$$

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.

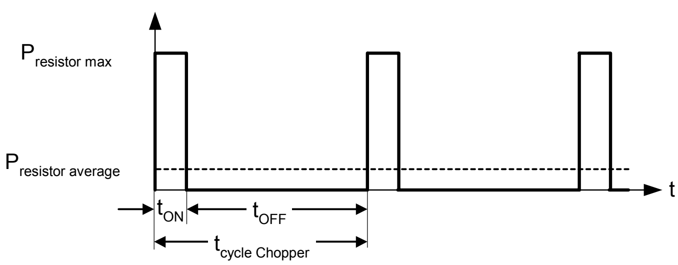
2.2 Load duty cycles and the load capability of the braking chopper

In order to protect the connected braking resistor, a load duty cycle for braking operation must be entered at the MM440 frequency converter using parameter P1237. For the braking resistors assigned to the MM440 frequency converter in Catalog DA51.2, a permissible load duty cycle is specified as 5%. The braking chopper integrated in the MM440 frequency converter can have a continuous load of the maximum braking power $P_{braking\ resistor\ max} = V_{DC\text{-}max}{}^2 / R_{min}$ (refer to Table 1). 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 $P_{braking\ resistor\ max}$, 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 braking resistors), then for an appropriately high braking power, the braking chopper can brake for the maximum duration t_{ON} with the maximum braking power $P_{braking\ resistor\ max}$. After this time expires, the selected load duty cycle (e.g. 5%) is 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 voltage would increase and the frequency converter would be shutdown (tripped) at the DC link overvoltage 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 $P_{braking\ resistor\ max}$ for the maximum duration t_{ON} followed by the continuous power $P_{braking\ resistor\ average}$. For cyclic operations, after braking with the maximum braking power $P_{braking\ resistor\ max}$ for the maximum duration t_{ON}, there must be a no-load time t_{OFF} before the maximum braking power $P_{braking\ resistor\ max}$ 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 $P_{braking\ resistor\ max}$, 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.



P1237	t_{ON}	t_{OFF}	$t_{cycle\ chopper}$	$P_{resistor\ aver.}$
5 %	12.0	228.0	240.0	0.05
10 %	12.6	114.0	126.6	0.10
20 %	14.2	57.0	71.2	0.20
50 %	22.8	22.8	45.6	0.50
100 %	Infinite	0	Infinite	1.00

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).

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.

3 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, that 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% ($t_{cycle\ chopper}$ = 240s) and 10% ($t_{cycle\ chopper}$ = 126.6s) this is guaranteed. For a load duty cycle that is selected to be ≥ 20% in parameter P1237, the load duty cycle duration $t_{cycle\ chopper}$ 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).

3.1 Maximum braking power

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

$$P_{braking\ appl\ max} \leq P_{braking\ resistor\ max}$$

$P_{braking\ appl\ max}$: Maximum peak braking power that occurs for the application

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

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

$$P_{braking\ resistor\ max} = V_{DC\text{-}max}{}^2 / R_{braking\ resistor}$$

As has already been mentioned, this value is a peak value that cannot be fully utilized in practice because of the proximity to the overvoltage shutdown threshold. For safe braking operation with a sufficient safety margin to the overvoltage shutdown threshold, 5% must be subtracted from this maximum braking power $P_{braking\ resistor\ max}$.

A minimum resistor value R_{min} must be maintained in order to protect the chopper transistor (refer to Table 1). The peak braking power of the braking chopper $P_{braking\ resistor\ max}$ 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 frequency converter in sizes A-F is as follows:

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

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

3.2 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 DA51.2 have an average braking power of approx. 5% of the maximum braking power (refer to Table 1). If this average braking power of the MM440 braking resistor is too low for the application, then when 4x MM440 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.

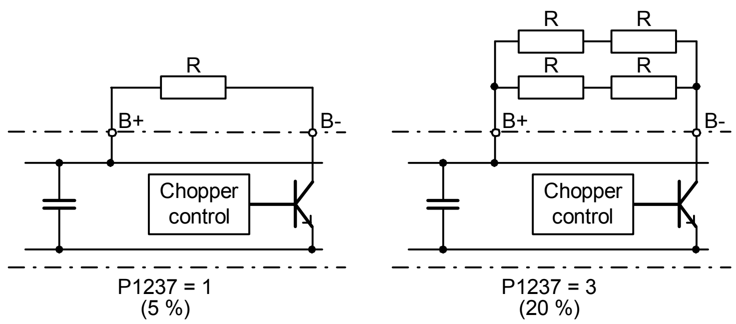


Fig. 7: Increasing the continuous braking power using 4x MM440 braking resistors

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 is that 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 $P_{braking\ resistor\ average}$ 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 $t_{cycle\ chopper}$ of the braking chopper (refer to Fig. 6). If the load duty cycle of the application $t_{cycle\ appl}$ is less than the load duty cycle duration $t_{cycle\ chopper}$ of the braking chopper, then the average braking power of the application $P_{braking\ appl\ average}$ can be directly compared to the average permissible braking power $P_{braking\ resistor\ average}$:

$$t_{cycle\ appl} \leq t_{cycle\ chopper}$$

$$P_{braking\ appl\ average} \leq P_{braking\ resistor\ average}$$

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

1	2	3	4	5	6	7	8
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 / R_{min} (Ω)**	**Maximum DC link voltage $V_{DC\ max}$ (V)**
4BC05-0AA0	A	200 - 240	0.12 - 0.75	50	980	180	420
4BC11-2BA0	B	200 – 240	1.1 - 2.2	120	2600	68	420
4BC12-5CA0	C	200 – 240	3.0	250	4500	39	420
4BC13-0CA0	C	200 – 240	4.0 - 5.5	300	6500	27	420
4BC18-0DA0	D	200 – 240	7.5 - 15.0	800	16800	10	410
4BC21-2EA0	E	200 – 240	18.5 - 22.0	1200	24700	6.8	410
4BC22-5FA0	F	200 - 240	30.0 - 45.0	2500	51000	3.3	410
4BD11-0AA0	A	380 - 480	0.37 - 1.5	100	1800	390	840
4BD12-0BA0	B	380 – 480	2.2 - 4.0	200	4400	160	840
4BD16-5CA0	C	380 – 480	5.5 - 11.0	650	12600	56	840
4BD21-2DA0	D	380 – 480	15.0 - 22.0	1200	24900	27	820
4BD22-2EA0	E	380 – 480	30.0 - 37.0	2200	44800	15	820
4BD24-0FA0	F	380 - 480	45.0 - 75.0	4000	82000	8.2	820
4BE14-5CA0	C	500 - 600	0.75 - 5.5	450	8600	120	1020
4BE16-5CA0	C	500 – 600	7.5 - 11.0	650	12700	82	1020
4BE21-3DA0	D	500 – 600	15.0 - 22.0	1300	26700	39	1020
4BE21-9EA0	E	500 – 600	30.0 - 37.0	1900	38500	27	1020
4BE24-2FA0	F	500 - 600	45.0 - 75.0	4200	86700	12	1020

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

Information on columns 1- 8 of Table 1:

Column

1: Order number of the assigned MM440 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 $P_{braking\ resistor\ average}$ of the assigned MM440 braking resistor with a load cycle duration of 240s.
6: Maximum achievable peak braking power $P_{braking\ resistor\ max}$ 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 overvoltage shutdown threshold. In order to achieve safe braking operation with sufficient safety margin to the overvoltage shutdown threshold, then 5% must still be subtracted from the maximum braking power $P_{braking\ resistor\ max}$.

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). 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 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 overvoltage condition.

3.3 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_{conv}	= 5.5kW
Max. braking power of the braking chopper in the freq. converter:	$P_{braking\ resistor\ max}$	= 12.6kW
Motor rated power:	$P_{motor\ N}$	= 5.5kW
Motor efficiency:	η_{motor}	= 0.865
Motor rated speed:	$n_{motor\ N}$	= 2925 RPM
Motor moment of inertia:	J_{motor}	= 0.015kgm²
Moment of inertia of the grinding wheel (referred to the motor):	J_{grind}	= 0.4kgm²
Max. motor speed for the application:	n_{max}	= 2900 RPM
Grinding disk braking time:	$t_{brake\ appl}$	= 5s
Load duty cycle duration of the application:	$t_{cycle\ appl}$	= 15s

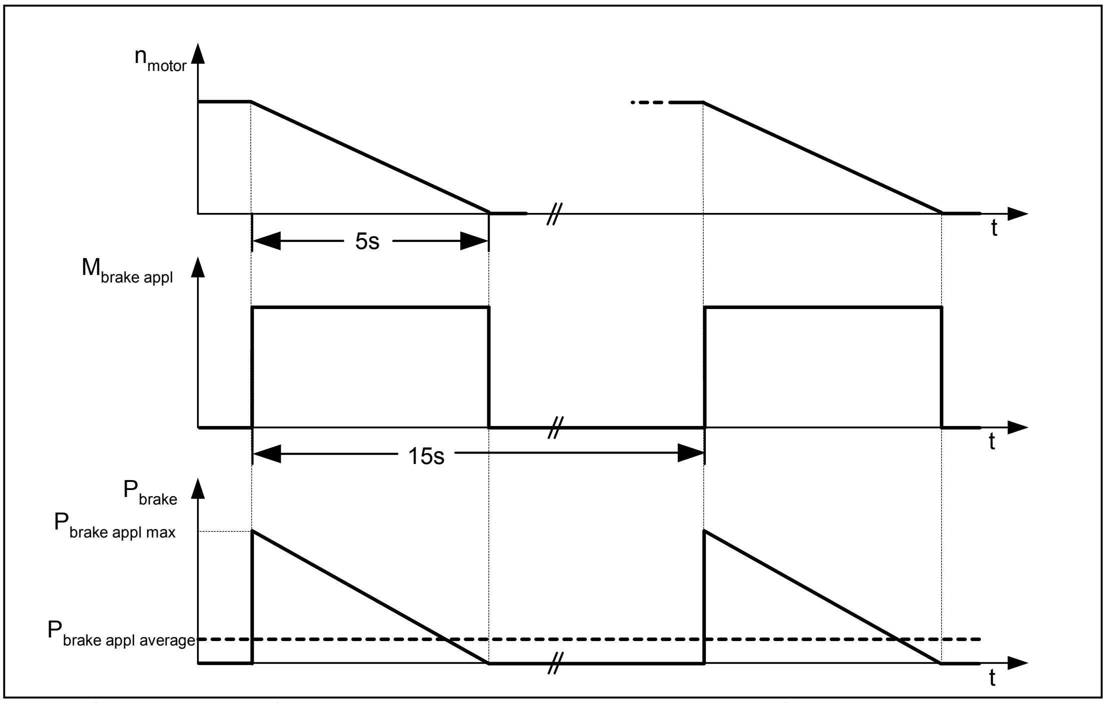


Fig. 8: Characteristic of the braking torque and the braking power for the application example

1. Checking the maximum braking power:

Braking torque:

$$M_{brake\ appl} = \frac{(J_{motor} + J_{grind}) \bullet n_{max}}{9.55 \bullet t_{brake\ appl}}$$

$$M_{brake\ appl} = \frac{(0.015kgm^2 + 0.4kgm^2) \bullet 2900\ RPM}{9.55 \bullet 5s} = 25.2\text{Nm}$$

Maximum braking power:

$$P_{brake\ appl\ max} = \frac{M_{brake\ appl} \bullet n_{max}}{9550} \bullet \eta_{motor}$$

$$P_{brake\ appl\ max} = \frac{25.2Nm \bullet 2900\ RPM}{9550} \bullet 0.865 = 6.6\text{kW}$$

This means that the condition **$P_{\text{brake appl max}}$ (6.6kW) ≤ $P_{\text{braking resistor max}}$ (12.6kW)** is fulfilled.

2. Checking the average braking power:

Average braking power in the application load duty cycle 15s:

$$P_{appl\ average} = \frac{1}{2} \bullet P_{appl\ max} \bullet \frac{t_{brake\ appl}}{t_{cycle\ appl}}$$

$$P_{appl\ average} = \frac{1}{2} \bullet 6.6kW \bullet \frac{5s}{15s} = 1.1\text{kW}$$

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

$$\mathbf{t_{cycle\ appl}\ (15s) \leq t_{cycle\ chopper}\ (71.2s)}$$ and

$$\mathbf{P_{brake\ appl\ average}\ (1.1kW) \leq P_{braking\ resistor\ average}\ (2.6kW)}$$

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 1.25kW, 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 braking resistor (56Ω). The maximum peak braking power that can be dissipated in the 80Ω resistor is given by:

$$\mathbf{P_{braking\ resistor\ max} = V_{DC\text{-}max}{}^2 / R_{braking\ resistor} = 840^2V^2 / 80\Omega = 8.82kW}$$

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 $P_{brake\ appl\ average}$ = 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 $P_{braking\ resistor\ max}$ (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 $t_{cycle\ chopper}$ (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 braking resistors in series as the total (summed) resistor of 2 • 56 Ω = 112 Ω would result in a maximum peak braking power of 6.3kW - that is too small.*
- *The maximum braking power $P_{braking\ resistor\ max}$ from Table 1 is not achieved for the application example so that sufficient safety margin to the overvoltage shutdown threshold is guaranteed.*

3.4 Flow diagram

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

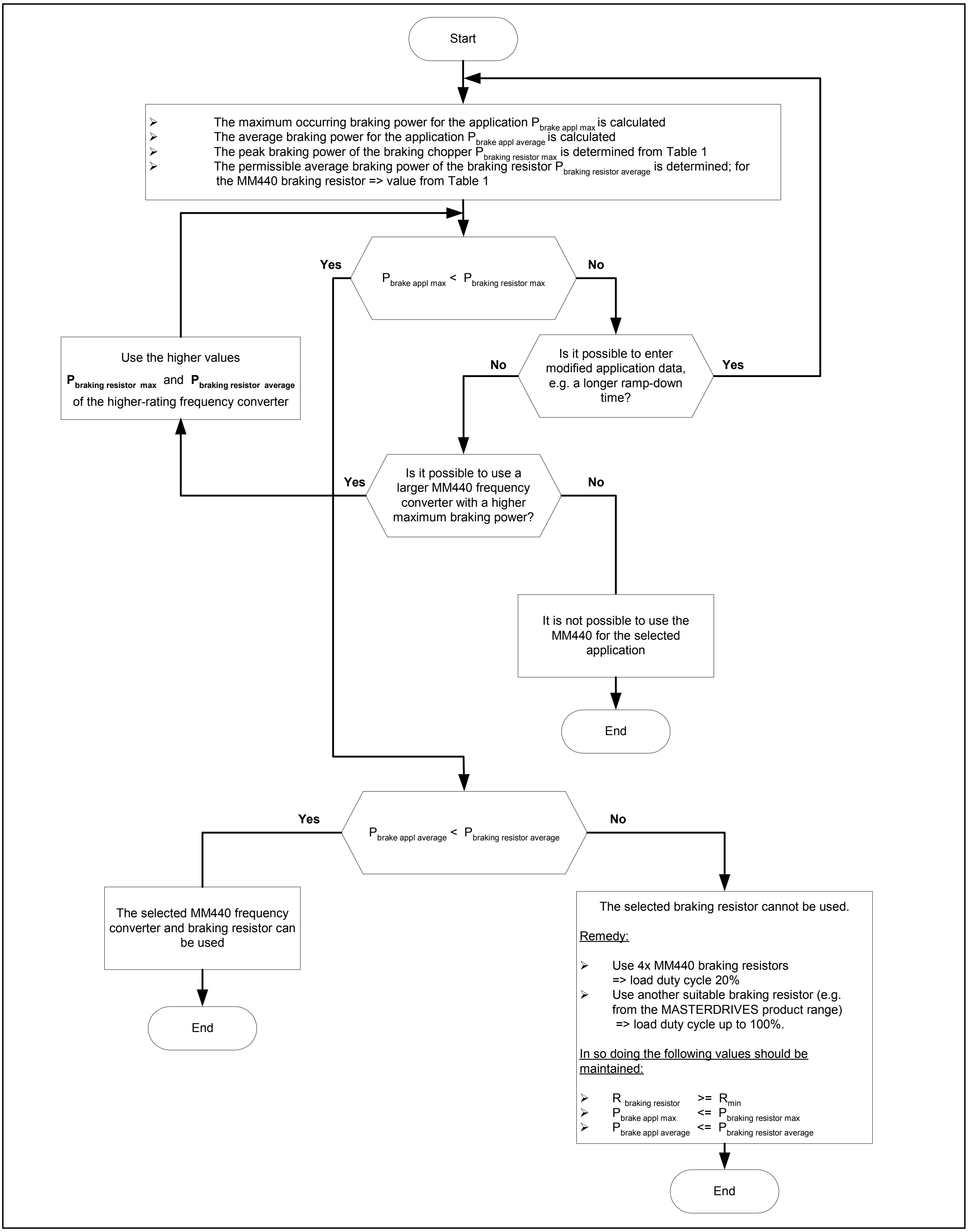


Fig. 9: Flow diagram to check the braking powers

3.5 Braking resistors

The MM440 braking resistors, assigned in Catalog DA51.2 are predominantly used as the braking resistors (refer to Table 1). The average braking power of the braking resistors $P_{braking\ resistor\ average}$ is approx. 5% of the maximum braking power $P_{braking\ resistor\ max}$ (5% load duty cycle). In order to increase $P_{braking\ resistor\ average}$, 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 $P_{braking\ resistor\ max}$ does not change as the resulting value of the resistance at R_{min} remains the same. As an alternative, other braking resistors with a higher average braking power $P_{braking\ resistor\ average}$ (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. 200 V – 240 V AC devices: 450V DC
  - 3-ph. 380 V – 480V AC devices: 900V DC
  - 3-ph. 500 V – 600V AC devices: 1100V DC
- $R_{braking\ resistor} \geq R_{min}$ (values for R_{min}, refer to Table 1)
- $P_{brake\ appl\ max} \leq P_{braking\ resistor\ max}$

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

  $P_{braking\ resistor\ max} = V_{DC\text{-}max}{}^2 / R_{braking\ resistor}$
  (minus 5% due to the safety margin to the overvoltage shutdown limit)
- $P_{brake\ appl\ average} \leq P_{braking\ resistor\ average}$
  (the load duty cycle of the resistor must in this case be greater than the load duty cycle duration of the braking chopper $t_{cycle\ chopper}$)

The following applies:

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

The Internet addresses of potential braking resistor manufacturers 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/seiten/prod_bw_3.html
- GINO, D-53117 Bonn http://www.gino.de/produkte/welcome.htm
- Koch, D-76698 Ubstadt http://www.koch-mk.de/

3.5.1 Connecting the braking resistor

The braking resistor is connected at terminals B+ / DC+ and B- of the frequency converter. 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 frequency converter and braking resistor (Sizes A-F) is 25m (shielded).

3.5.2 Thermal protection for the braking resistor

The connected MM440 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 braking resistors - as shown in Fig. 7 - the value "3" (20% load duty cycle). When third-party braking resistors are used, under certain circumstances, 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.

3.6 Operation together with other types of braking

Regenerative braking using braking resistors is the most effective and most accurate braking technique for the MM440 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.

3.7 DC link voltage controller

If the braking chopper of the frequency converter is activated, then the V_{DCmax} controller of the frequency converter (parameter P1240) must be de-activated as both functions mutually influence one another and can cause the frequency converter to malfunction. The V_{DCmin} controller of the frequency converter can however be activated (kinetic buffering, that can also be set using parameter P1240).

3.8 Summary of the frequency converter parameters that are important for regenerative operation

MM440 parameters	Comment
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.
P1132	**Ramp-down initial rounding time:** An ramp-down initial rounding-time reduces the maximum braking power
P1230-P1234	**DC braking:** This can, for example, be activated to lock the motor **after** regenerative braking down to zero speed (resistor braking).
P1236	**Compound braking:** This may not be simultaneously activated with the resistor braking due to the same response thresholds.
P1237	**Resistor braking:** This is activated by setting a value greater than "0". This enters the load duty cycle for the braking chopper.
P1240	**V_{DC} controller:** When resistor braking is activated, this may not be set to the value “1” or “3”.
r1242	**Switch-on signal level $V_{DC\ max}$ controller:** The braking chopper switches-in at $V_{DC\ chopper}$ = 0.98 • r1242. The value for r1242 is newly sensed each time that the frequency converter is connected to the line supply.
P1254	**Automatically sensing the $V_{DC\ max}$ switch-in level:** This function is de-activated for the setting "0". Setting then with P210 (line supply voltage).

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