1. Micro Drive Load sharing application note

1.1 Index

1.2 Abstract

Load sharing gives the possibility to connect multiple Micro Drive over the same DC-link with the following benefits.

Energy savings
When a motor runs in regenerative mode it can supply the other drives that are running in motoring mode. The alternative is to use a brake resistor on each single drive, to consume the energy when the motor runs in regenerative mode.

Brake resistor
Typically only one common brake resistor is needed instead of a brake resistor for each drive.

Power back-up
At mains failure all the Micro Drive can be supplied through the DC-link from a backup. The application can be shut down in a controlled way or the application can continue running.

1.3 Limitations and special conditions

WARNING: Some voltage related functions may not operate or may operate at reduced performance levels while using load sharing. Example: A drive without brake is combined with a drive with brake. When the drive with brake breaks the other drive will get an over current warning. Although inconvenient, the performance will be maintained.

- AC-brake will not work as expected. This function checks for regenerative power but in a load sharing application the regenerative power can be power from another drive. Therefore AC-brake should be turned off in load share applications (Par 2-10 *Brake Function*).

NOTE: The mains supply must have its own missing phase- and over current protection. DC-link has higher capacity and one or more drives can have their rectifier overloaded even though the DC-link does not show a high level of voltage ripple. Therefore it is important the mains supply is equipped with missing phase and over current protection

NOTE: The start-up time of the drives may increase.

- The drive must be equipped with load sharing terminals
    - All Micro Drive M1-M5 have UDC+,UDC- terminal as default can be used as loading sharing terminal.

- Load sharing is only possible within the Micro Drive.

- Load sharing is only possible within the same voltage class, e.g. use T4 with T4 only.

- It is recommended to monitor if all the drives are ready (“drive ready” -signal) and take it into account in the overall application control

- Drives used for load sharing must be placed physically close to each other to allow the wiring between them to be as short as possible, a maximum of 25 m. In addition the two wires must be close to each other, twisted if possible, and built symmetrically around the drives(s) with highest power

- When adding a brake resistor in a load sharing configuration, all drives must be equipped with a brake chopper

1.4 Inrush control by frame sizes

The concept for limiting the inrush current in the Micro Drive DC-link capacitors is all the same for all frame sizes M1~M5.

NOTE: It is important to be aware of the differences in concept before combining drives in a load sharing application. By not doing this, the consequence can be a fatal destruction of the drive!

The principles are listed in Table 1.

Frame size	Principle
M1	DC inrush self limited
M2	
M3	
M4	
M5	

Table 1 Principles of inrush control for individual frame sizes.

In order to understand the concept, it is necessary to distinguish between the two situations

1. Drive supplied from mains and supplying others via load sharing terminals
2. Drive supplied from load sharing terminals

1.4.1 Micro drive Frame sizes

The Micro drive inrush control is placed in series with the DC-link capacitors which controls the current coming from mains and/or the load sharing terminals.

Power via Mains

If Micro drive is powered from mains they cannot control and limit the inrush to other frequency converters connected via the load sharing terminals.

Power via Load Share Terminals

The Micro drive inrush control successfully limits inrush current when powered from the load sharing terminals.

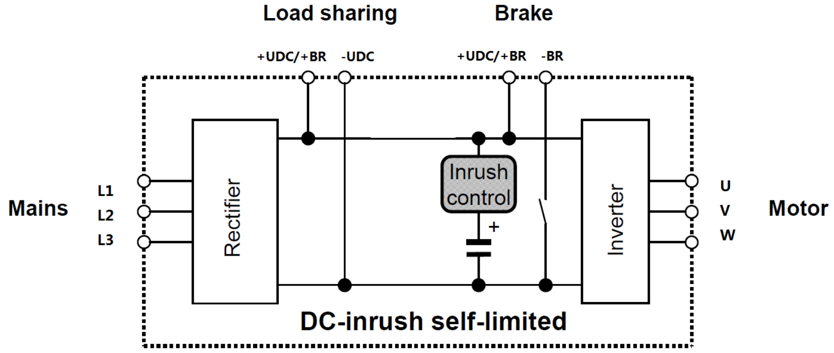

Figure 1 Inrush principle for Micro drive M1~M5.

1.4.2 Frame size Combinations

Due to the different principles for inrush control, care must be taken when Micro drive combining different type of inrush principle.

- Micro drive M1~M5 ***can*** be combined with other Micro drive frame sizes M1~M5 in load sharing.
- When Micro drive with other type of inrush principle. In this combination the Micro drive ***can not*** be connected to mains. See Figure 2.

WARNING: There exists a severe risk of destroying the Micro drive if they are connected to mains while being connected to other inrush principle drives via load share. This is a result of the fact that the rectifier in the Micro drive M1~M5 will be heavily overloaded during both inrush and normal load condition.

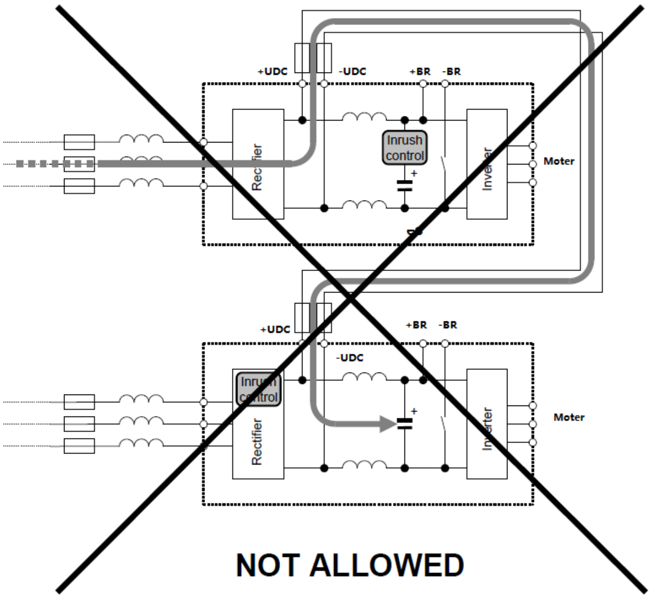

Figure 2 No inrush limitation when Micro drive are supplied from mains and combined with AC-inrush limit.

1.5 Load sharing configurations

The most typical load sharing configurations are discussed.

a) All drives supplied from an external DC supply

b) One large drive supplied from mains supplies all others

c) All drives supplied individually from mains

d) Using a DC-link back-up

e) Using a brake resistor

f) Using a re-generative unit

NOTE: All national regulations have to be followed and is the responsibility of the installer.

1.5.1 External DC supply with soft charge

If the external DC supply is equipped with inrush limitation, all frame sizes can be added on the load share terminals

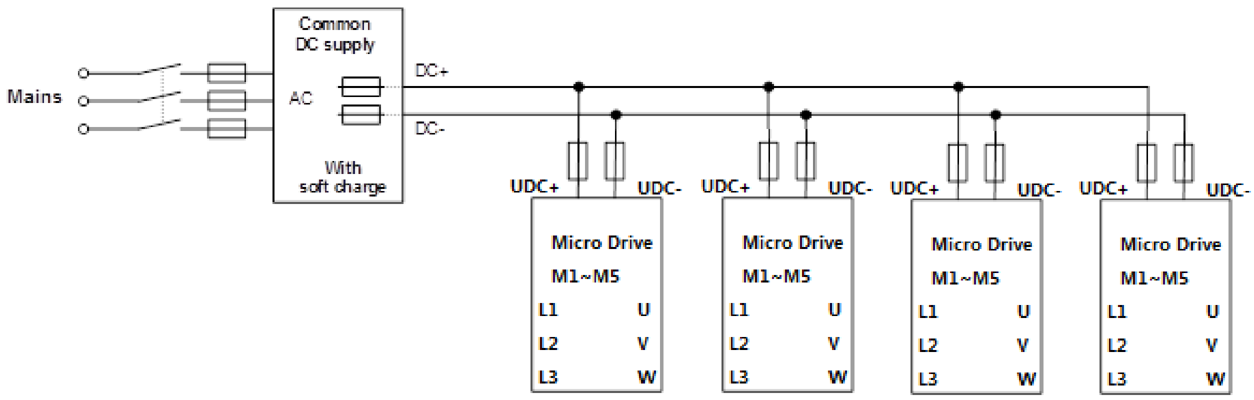

Figure 3. The drives are supplied from an external DC supply via the load share terminals. The DC supply has soft charge.

No AC line reactors are necessary as the intermediate voltage is the same for all the connected drives.

To comply with relevant regulations and prevent further destruction from short circuits in a single drive, it is required to fuse the load sharing terminals. Without individual fuses on the load share terminals, there is a risk that a broken drive will be charged by the working drives.

The DC-coils in the drive will limit the ripple current and minimize the harmonic current to the common DC-supply.

Requirements for the external DC supply

- The common DC-supply must limit the inrush current to the capacitive load related to the intermediate circuits of the drives connected in parallel. For simplicity the input impedance of the common DC-link can be calculated as the total capacitance of the DC-link in parallel.

- The supply must be able to withstand short mains drop out and associated current spikes related to these. The supply must observe the EMC requirements for the application itself or with additional RFI-filters etc.

- The external DC-supply must be able to supply all connected drives and should be equipped with the necessary fuses, mains switch and RFI filter.

1.5.2 One large drive supplied from mains supplies all others

In this configuration only the large drive is connected to mains.

Micro drive can be connected to the Load share terminals and supplied from the large drive. The large drive can be any frame size as long as it is the largest drive in the load sharing configuration.

The large drive has to be dimensioned so it has capacity enough to supply the remaining drives. This means the drive be dimensioned to supply the total motor power. For example, the large drive could run a large flywheel and only provide power enough to overcome the friction after the start up; if the normal AC power should disappear, the mechanical inertia can be used to supply power via the common DC-bus to smaller VLT frequency converters. Possible application area is the textile industry.

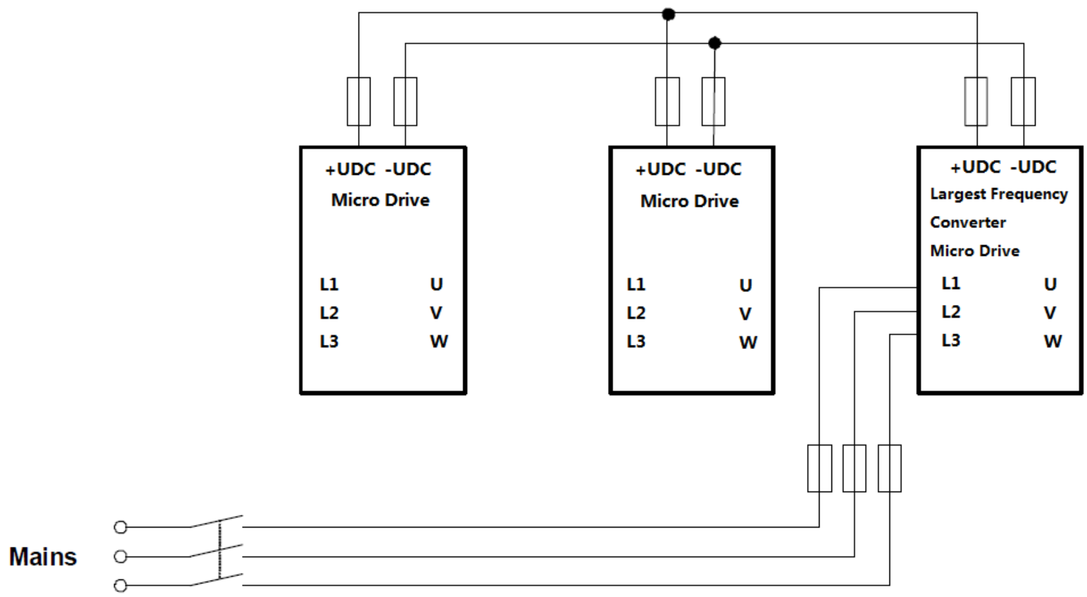

Figure 4 One large drive supplies the others via load share terminals.

Components such as mains fuses and Line reactors can be saved for the drives that are not connected to mains. Also, because only one drive is connected to mains it does not require any AC line reactors. Fuses in the DC-link are still required to comply with relevant legislation.

1.5.3 All drives supplied individually from mains

This configuration is a typical load sharing application. If one or more motors are driven into regenerative mode, they deliver power to the common DC-link. This power is then used by other drives, and in this way the installation is more efficient. Also, in some cases this eliminates the need for a brake resistor.

WARNING: The mains fuses/ circuit breakers must be selected so that a cleared circuit can cause the remaining fuses to clear if the load from the system is too high. The consequence of not doing this is

that a potential clearing of one drive's fuse will overload the remaining drives in the load sharing application.

Micro drive can be combined in a load sharing application when supplied by mains without special considerations.

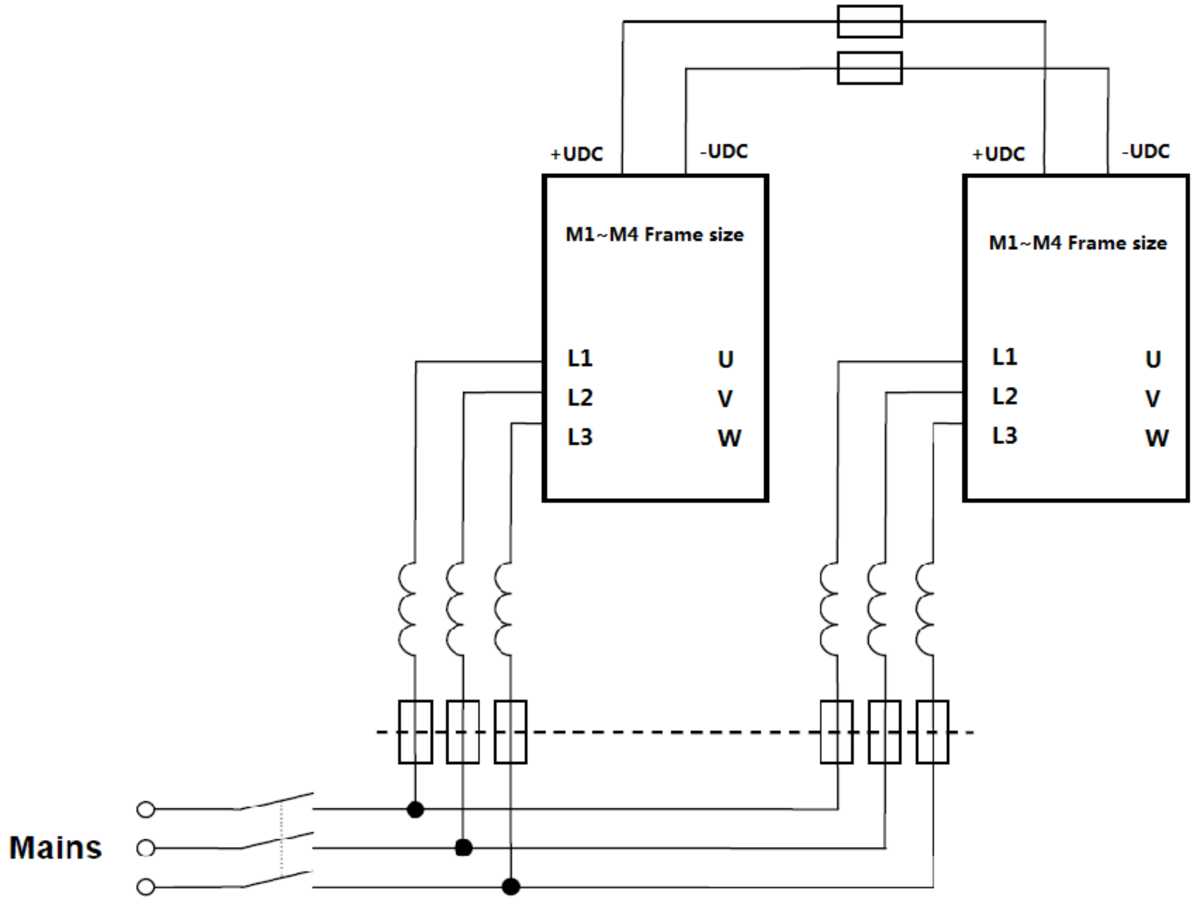

Figure 5 Load sharing with Micro drives M1~M4 frame sizes supplied from mains and connected via Load share terminals.

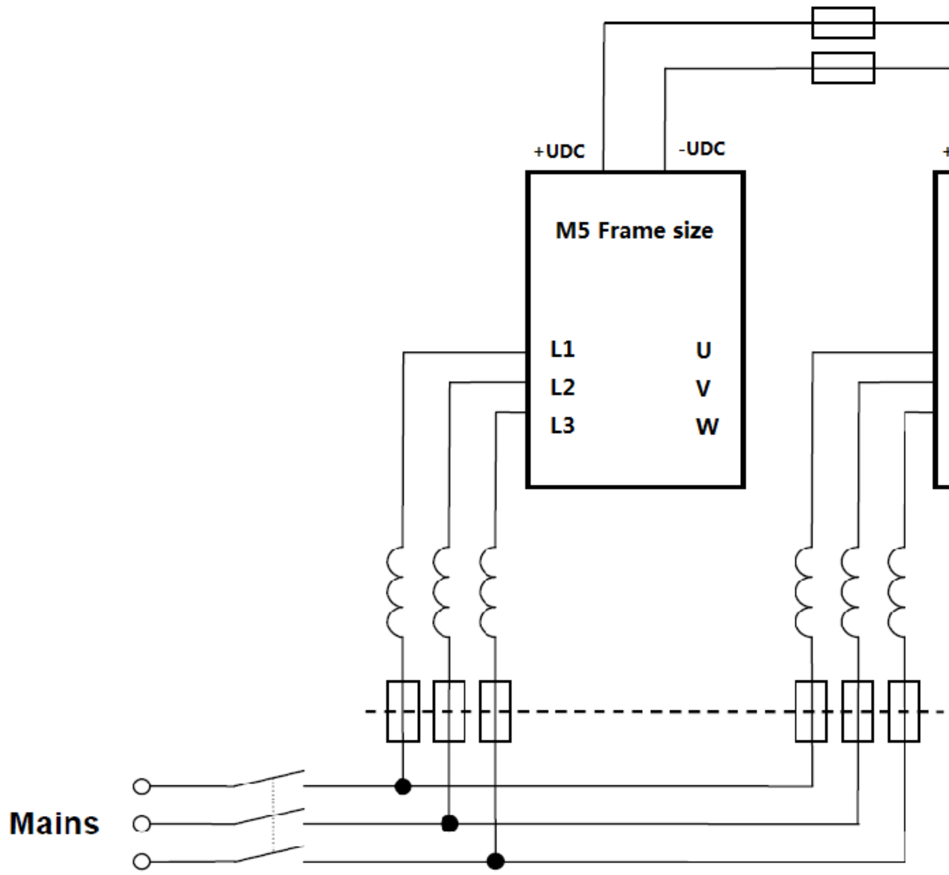

Figure 6 Load sharing with Micro drives M5 frame sizes supplied from mains and connected via Load share terminals.

WARNING:

Risk of destroying the drives if connecting Micro Drive to mains while being connected to other type of AC-inrush limited principle on the load share terminals

M1~M4 Frame size is only allowed to load sharing with M1~M4. M5 frame size can only load sharing with M5. No mix M1~M4 together with M5 in load sharing!

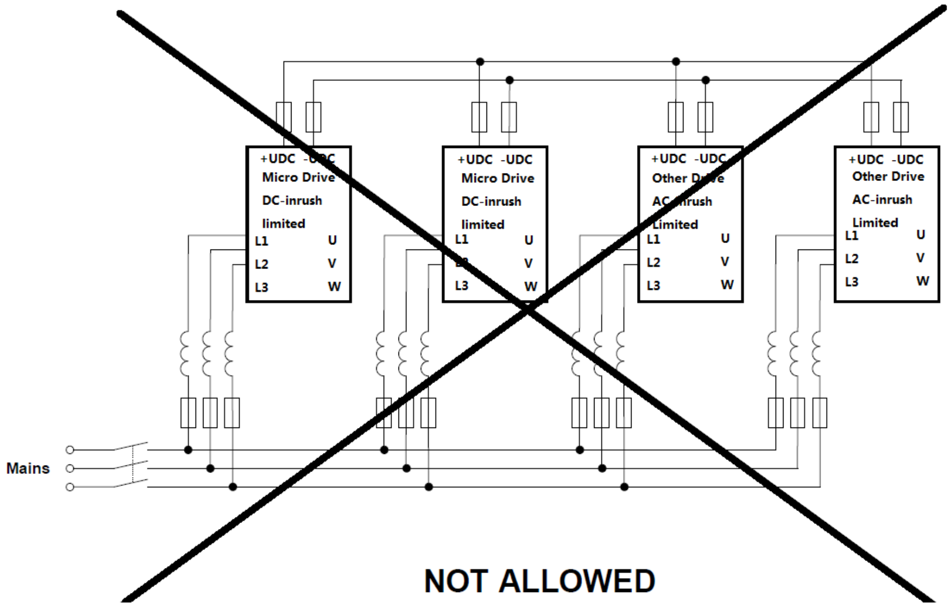

Figure 7. Load sharing among Micro Drive and other drives AC-inrush limited from mains and connected via load share terminals is not allowed.

The total power of the installation is the sum of the nominal powers of the drives connected to mains. This means that the drives connected to mains can not be used at their full capacity as they are sharing their capacity with the drives connected by load share terminals.

The number of power up is limited to maximum twice per minutes.as there must be time for cooling down of the drive. This is mostly relevant for the biggest power size in each frame size.

In this configuration the DC capacitors voltage (intermediate voltage) can be slightly different from drive to drive due to differences in the mains rectifiers, different temperature, etc. This small difference in DC voltage requires installation of AC line reactors for each drive. Furthermore, it is also requires fuses in the DC-bus.

1.5.4 Using a DC-link back-up

A battery backup can be added to the common DC-link and back-up can be supplied to all the drives during mains failure. The application can be closed down as a controlled process or the application can be running continuously.

The battery backup must contain soft charge and isolation. The principles are shown in

Figure . An isolation diode is placed in series with battery supply, so the drives can not charge into the batteries. Circuitry is placed for inrush limitations.

Care must be taken on how to connect and disconnect the battery backup to the Load share terminals of the drives.

During a stand-by situation the stand-by consumption of the drives will proceed draining the battery in the battery back-up.

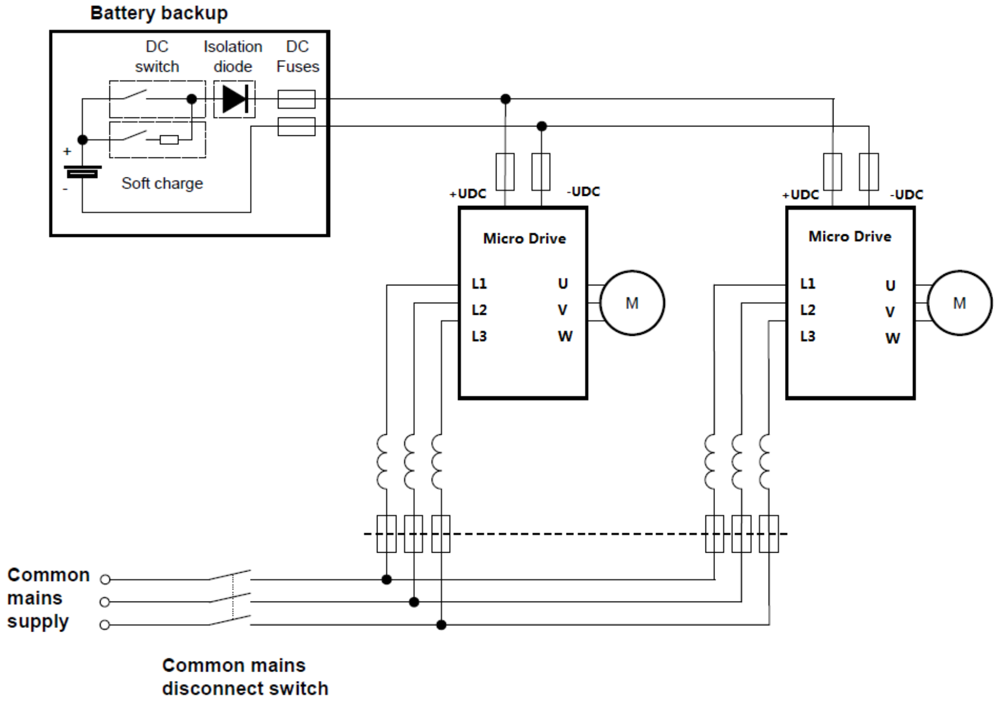

Figure 8 Principal figure for load sharing w. battery backup

WARNING:

M1~M4 Frame size is only allowed to load sharing with M1~M4. M5 frame size can only load sharing with M5. No mix M1~M4 together with M5 in load sharing!

1.5.5 Using a brake resistor

For applications where the regenerative loads require removal of energy from the DC-link this can be established by adding a resistor.

As the DC-link connects the drives, it is possible to use only one brake resistor to dissipate the energy. The brake resistor must be dimensioned to dissipate the maximum energy from braking of the motors and must be connected to a drive that can withstand the braking power.

In Figure is shown a typical load sharing application with brake. Often it is sufficient to add a brake to only one of the units as it can remove energy from all the drives in the application.

NOTE: The brake resistor must be connected to the drive with the largest power

WARNING: Risk of destroying the drives if connecting Micro Drive to mains while being connected to AC-inrush limited principal Drive on the load share terminals

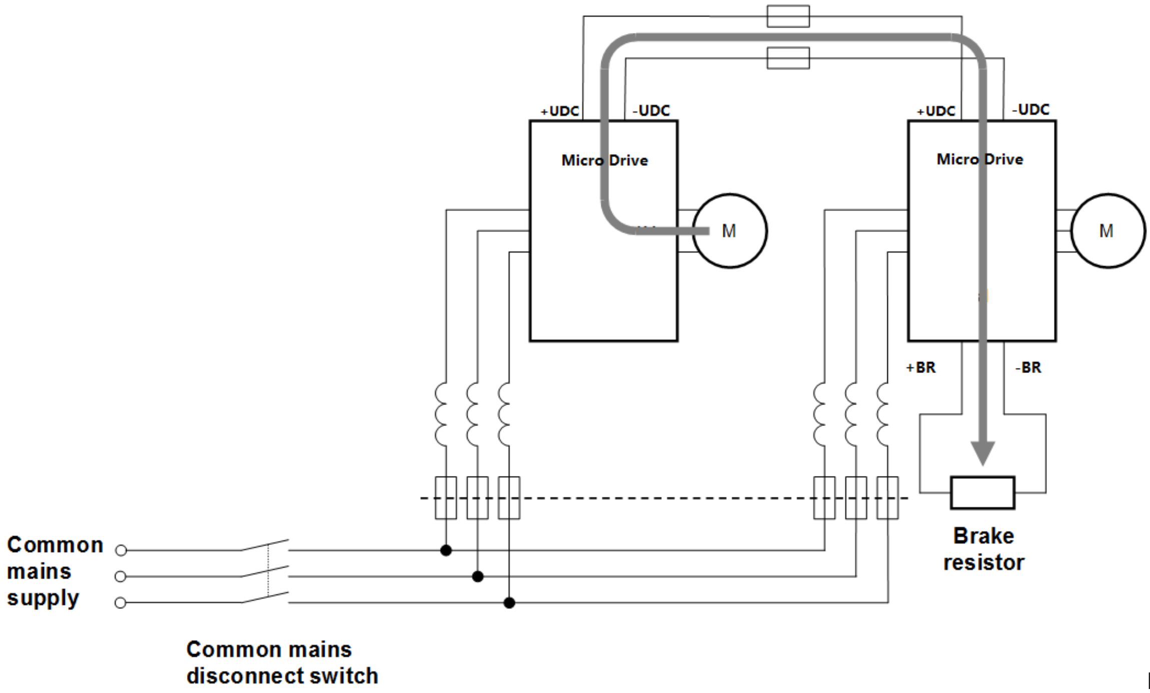

Figure 9 Load sharing w. resistor brake. Energy flow from one unit to another w. brake

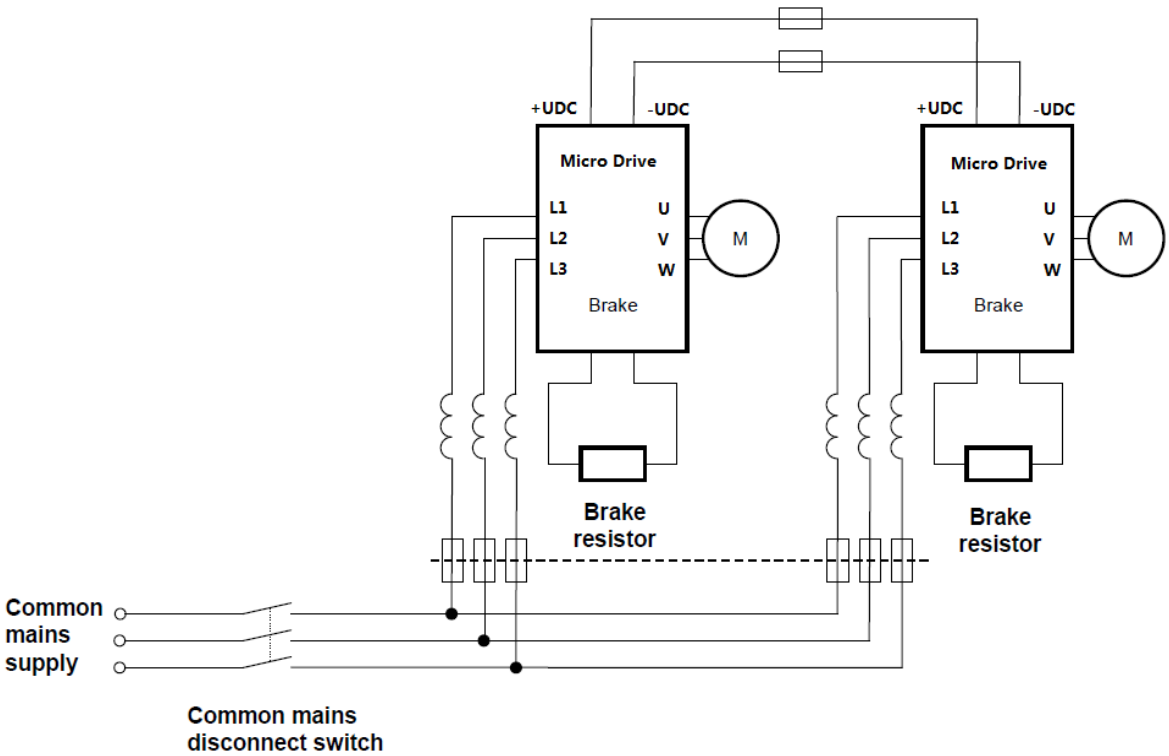

Figure 10 Another common set-up is to equip all drives in the load sharing with a resistor brake.

NOTE: It can NOT be taken for granted the brakes will share the loads proportionally to the resistor resistance value. Possibly, only one brake be 100% "ON" before the next brake will start braking. This is due to tolerance between each drive's DC link voltage measurements.

1.5.6 Using a re-generative unit

A re-generative unit can be connected to the common DC-link and power can be transferred back to mains.

In general the same requirements apply as for section **Error! Reference source not found.**. but further it should be noted the voltage working range of the DC-link must be observed and taken into account. The re-generative unit must be able to keep the DC-link voltage below nominal mains supply +13% multiplied by sqrt(2) and thereby below the actual value for braking.

For further guidance and information on how to install a regenerative unit refer to vendor installation guidance.

WARNING:

Risk of destroying the drives if connecting Micro Drive to mains while being connected to AC-inrush limited principal Drive on the load share terminals.

M1~M4 Frame size is only allowed to load sharing with M1~M4. M5 frame size can only load sharing with M5. No mix M1~M4 together with M5 in load sharing!

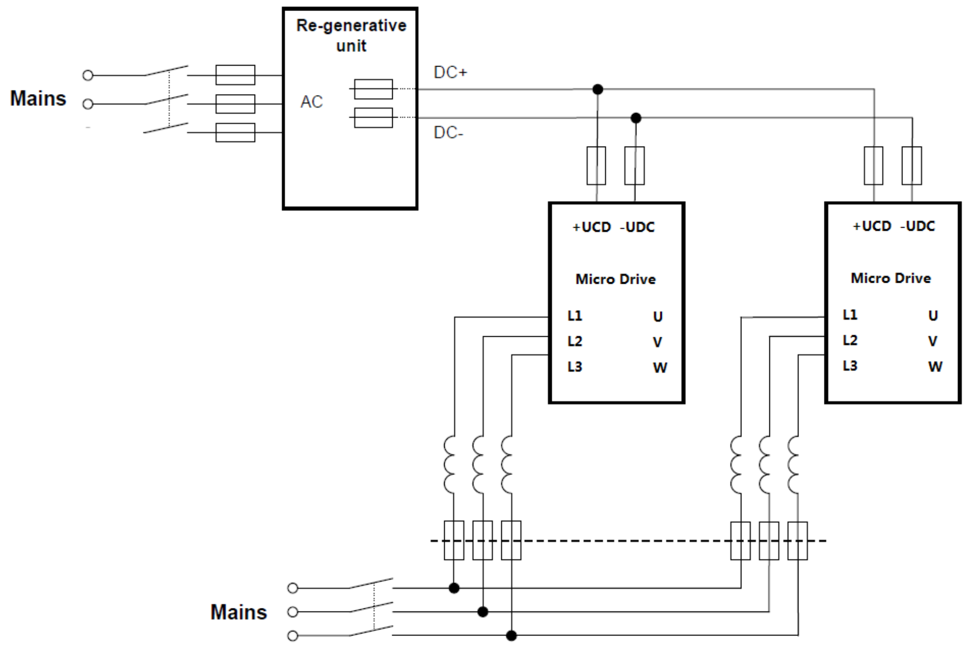

Figure 11 Load sharing using re-generative unit

1.6 Additional components needed for load sharing

In a load sharing application, some additional components are typically needed.

- DC fuses
- Mains fuses
- Line reactors
- Common mains disconnect switch

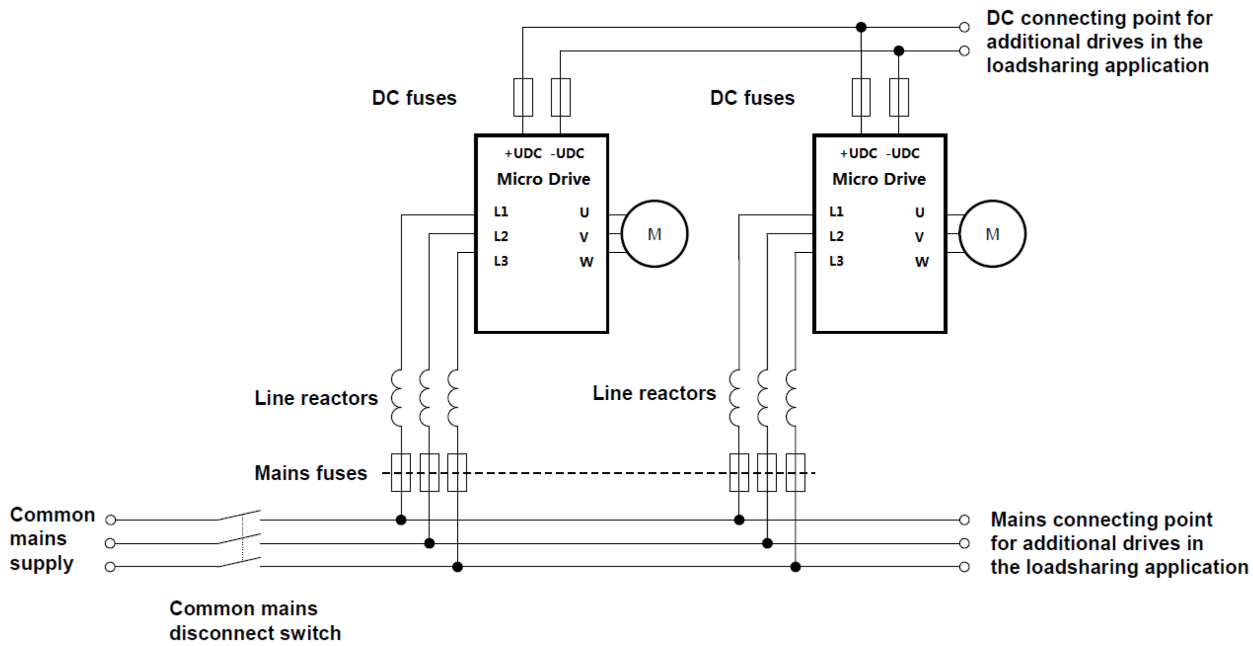

Figure 12 Typical load sharing application setup and the components needed.

1.6.1 DC fuses

Fuses must be installed in series with the load sharing terminals of all connected units. This is done to protect the DC bus against short-circuits and the drives from overload.

NOTE: Respect the following guidelines when dimensioning the DC bus fuses.

- The voltage class of the fuse must be able to handle the maximum DC bus voltage ($1{,}35 \cdot U_{LL}$)

- The fuse must be a fast semiconductor type, e.g. aR or gR. For guidelines to selecting a fuse, please refer to application note MN.90.T1.

- The maximum fuse current rating must not exceed the mains fuse current rating for the individual drive ($I_{fuse,DC-link,\max} \le I_{fuse,mains}$)

The recommended DC bus fuses below are based on equation Equation 1 and the fuse is selected one size up after rounding up to the next available fuse size. The nominal voltage, U_{LL} , is reduced by 10% as a worst case scenario in the calculation to allow for tolerances.

$$I_{DC} = \frac{P_{in}}{U_{DC}} = \frac{P_{in}}{1{,}35 \cdot U_{LL,n} \cdot 0{,}9}$$

Equation 1 Calculation of DC bus fuse. Remember to round one size up after rounding up to the next available fuse size.

Example: $U_{LL} = 230\text{V}$ and $\text{P}_{\text{in}} = 3{,}7\text{kW}$ gives $I_{DC} = 13{,}2\text{A}$. The next available fuse size is aR-16, hence aR-20 is selected.

NOTE: the recommendations are for ambient temperatures of around 20°C. At 40°C gR/ aR fuses are rounded one size further up, i.e. rounded up to the nearest fuse size AND TWO further sizes up. For high ambient temperatures, contact the fuse supplier.

Power[kW]	Recommended DC bus fuse size@ 230V [A]	Recommended DC bus fuse size@380V [A]
0.18	aR-4	
0.25	aR-4	
0.37	aR-4	aR-4
0.55	aR-5	aR-4
0.75	aR-5	aR-4
1.1	aR-5	aR-5
1.5	aR-8	aR-5
2.2	aR-10	aR-6
3	aR-16	aR-10
3.7	aR-20	
4		aR-12
5.5		aR-16
7.5		aR-25
11		aR-40
15		aR-40
18.5		aR-63
22		aR-63

Table 2 DC bus fuses.

1.6.2 Mains fuses

A frequency converter that works correctly limits the current it can draw from the supply. Still, it is demanded to use fuses and/ or Circuit Breakers on the supply side as protection in case of component break-down inside the frequency converter (first fault). This is mandatory in order to ensure compliance with IEC 60364 for CE or NEC 2009 for UL.

WARNING
Personnel and property must be protected against the consequence of component break-down internally in the frequency converter.

FC 51	Max. Fuses UL						Max. fuses non UL
	Bussmann	Bussmann	Bussmann	Littel fuse	Ferraz-Shawmut	Ferraz-Shawmut	
1X200-240 V							
kW	Type RK1	Type J	Type T	Type RK1	Type CC	Type RK1	Type gG
0K18-0K37	KTN-R15	JKS-15	JJN-15	KLN-R15	ATM-R15	A2K-15R	16A
0K75	KTN-R25	JKS-25	JJN-25	KLN-R25	ATM-R25	A2K-25R	25A
1K5	KTN-R35	JKS-35	JJN-35	KLN-R35	-	A2K-35R	35A
2K2	KTN-R50	JKS-50	JJN-50	KLN-R50	-	A2K-50R	50A
3x200-240 V							
0K25	KTN-R10	JKS-10	JJN-10	KLN-R10	ATM-R10	A2K-10R	10A
0K37	KTN-R15	JKS-15	JJN-15	KLN-R15	ATM-R15	A2K-15R	16A
0K75	KTN-R20	JKS-20	JJN-20	KLN-R20	ATM-R20	A2K-20R	20A
1K5	KTN-R25	JKS-25	JJN-25	KLN-R25	ATM-R25	A2K-25R	25A
2K2	KTN-R40	JKS-40	JJN-40	KLN-R40	ATM-R40	A2K-40R	40A
3K7	KTN-R40	JKS-40	JJN-40	KLN-R40	-	A2K-40R	40A
3x380-480 V							
0K37-0K75	KTS-R10	JKS-10	JJS-10	KLS-R10	ATM-R10	A6K-10R	10A
1K5	KTS-R15	JKS-15	JJS-15	KLS-R15	ATM-R15	A2K-15R	16A
2K2	KTS-R20	JKS-20	JJS-20	KLS-R20	ATM-R20	A6K-20R	20A
3K0	KTS-R40	JKS-40	JJS-40	KLS-R40	ATM-R40	A6K-40R	40A
4K0	KTS-R40	JKS-40	JJS-40	KLS-R40	ATM-R40	A6K-40R	40A
5K5	KTS-R40	JKS-40	JJS-40	KLS-R40	-	A6K-40R	40A
7K5	KTS-R40	JKS-40	JJS-40	KLS-R40	-	A6K-40R	40A
11K0	KTS-R60	JKS-60	JJS-60	KLS-R60	-	A6K-60R	63A
15K0	KTS-R60	JKS-60	JJS-60	KLS-R60	-	A6K-60R	63A
18K5	KTS-R60	JKS-60	JJS-60	KLS-R60	-	A6K-60R	80A
22K0	KTS-R60	JKS-60	JJS-60	KLS-R60	-	A6K-60R	80A

Table 3 Main fuses data.

WARNING: The mains fuses/ circuit breakers must be selected so that a cleared circuit can cause the remaining fuses to clear if the load from the system is too high. The consequence of not doing this is that a potential clearing of one drive's fuse will overload the remaining drives in the load sharing application.

1.6.3 Line reactors

The Line reactors are only needed if the drives are powered from mains.

In load sharing applications, the rectifiers of the drives are connected in parallel via the external DC bus connection. When drives with different power size are connected in load sharing or when drives of same power size are operated at different load conditions, the forward voltage drop of the rectifiers can be different. This may result in unbalanced compensation within the load sharing network and thus must be balanced out via Line reactors.

The Line reactors are placed in series with the mains fuses. They ensure that the load is shared proportionally to the nominal power of each drive and prevent damage to any rectifier.

NOTE: The Line reactors add a load dependent voltage drop. The voltage drop (ΔU%) of the drives must be the same for all drives in the load sharing network.

Tables with order numbers are provided for 50 Hz 230V and 380V.

NOTE: The values in Error! Reference source not found. **and Table 3 are for Normal Overload. Example: If a 22 kW FC-302 is used in Normal Overload, use 175U1009. If it is used in High Overload, use 175U0047 (see** Error! Reference source not found.**).**

The following formula can be used to calculate coils for 60Hz, for other voltage drops and for other mains voltages, not listed in **Error! Reference source not found.** and Table 3.

$$L[H] = \frac{U_{phase-0}[V] \cdot \Delta U_{\%}}{I_{In,\max}[A] \cdot 2\pi \cdot f[Hz]} = \frac{U_{LL}[V] \cdot \Delta U_{\%}}{I_{In,\max}[A] \cdot 2\pi \cdot f[Hz] \cdot \sqrt{3}}$$

FC-51 P [kW] 400V	Max I(in), continuous [A]	Line reactor current [A]	Voltage drop Uk [%]	AC coils L [mH]	AC coils code No.
0.37	1.9	2.6	0.73%	2.827	175U0017
0.75	3.5	2.6	1.35%	2.827	175U0017
1.5	5.9	5.3	1.11%	1.387	175U0024
2.2	8.5	7	1.21%	1.05	175U0025
3	11.5	9.1	1.26%	0.808	175U0026
4	14.4	12.2	1.18%	0.603	175U0028
5.5	19.2	15	1.28%	0.49	175U0029
7.5	24.8	32	0.78%	0.23	175U0030
11	33	37.5	0.88%	0.196	175U0031
15	42	44	0.95%	0.167	175U0032
18.5	34.7	60	0.58%	0.123	175U0034
22	41.2	60	0.69%	0.123	175U0034

Table 3 AC coil data

1.6.4 Common mains disconnect switch

The mains supply must be from the same source for all units in the load sharing network. When power is applied or removed it must be via a common disconnect switch.

If drives are powered on/off individually this might lead to blown fuses, or even unit destructions in certain cases unless special attention is made to interlock for proper power up- and down sequencing.

1.6.5 Example

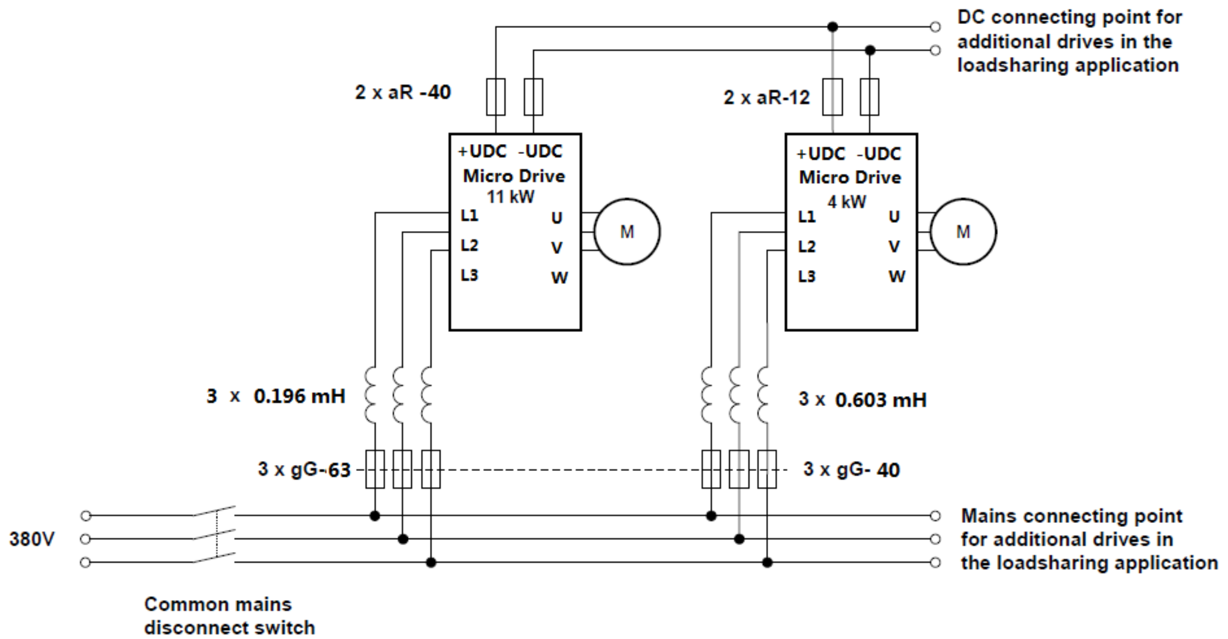

Figure 13 Example of load sharing with all drives supplied individually from mains. Values of DC fuses and Line reactors are taken from the tables in this application note and the values for mains fuses are taken from the Design Guide (also found in application note MN.90.T1)