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*Application Note*

# Unidrive

DC bus paralleling

Issue:1

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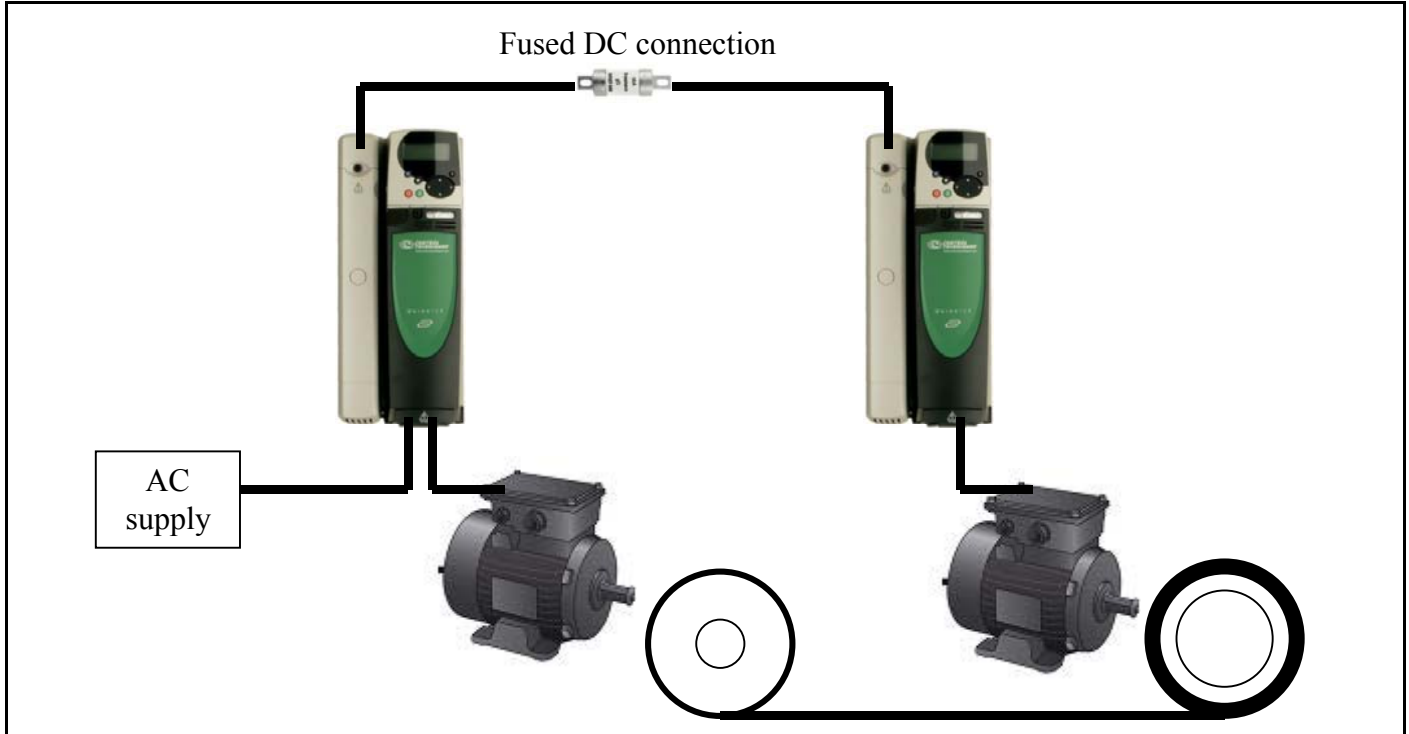


# 1 DC bus paralleling

## 1.1 Why connect DC buses together ?

In applications where regenerative energy is present for significant periods of time on one or more drives it is possible to recycle this current via the DC bus to another drive which is in the motoring condition. This improves the efficiency of the system since the regenerated energy is not wasted in braking resistors and the motoring drive draws substantially less power from the mains. This can be particularly advantageous where one or more drives may be 'holding back' a line to provide tension. It is often applied in high performance servo drive applications where substantial amounts of energy are used in accelerating and braking drives.

### Example of a Winder / Unwind solution



Another reason can be to save cost in an application where several drives can share a single braking resistor due to differing regenerative duty cycles between drives.

As well as offering advantages in terms of simplifying energy management, a common DC bus system also has the potential to simplify the mains connections and protection, as usually only a single mains feed is needed.

In summary the advantages are:

- Reduction of energy losses (heat loss from braking resistors)
- Reduce cubicle size
- Reduced input stage systems cost (reduced AC input cabling, AC input fuses, contactors etc.)
- System controlled power down on mains loss
- Common braking solutions

There are disadvantages however, and care needs to be taken in the implementation of such a system. The direct connection of the DC links of AC drives usually entails the direct connection of the DC link capacitor banks of all inverters. These capacitors store substantial amounts of energy. In the event of a fault, all the stored energy in all the DC link capacitors of the group of drives will be fed into the fault causing substantial damage to the original failed drive as well as to others. Protection can be afforded through the provision of fusing between the linking DC cabling and the individual drives in both lines.

### Fusing Policy

The subject of fusing in respect of common DC bus systems is somewhat confusing, only in the respect of the policy of some drive manufacturers who do not recommend fusing. Whilst in some cases the fuses are integral to the drive and are therefore present but not discussed, in others reliance is clearly placed upon the electronic monitoring and control to protect the drive. The merits of such a philosophy are unclear and it must be assumed that they are based upon a reliance on the DC link components, notably the DC link capacitors. Control Techniques policy is to recommend suitably rated fuses in each DC connection.

### NOTE

When supplying the drives via their DC bus connection, the UL listing may be invalidated. Please check with the supplier of the drive.

Having decided on a common DC bus system, it is necessary to decide upon the form of power supply connection. This is dependent upon many factors including:

- Requirement to regenerate energy back into the mains supply.
- Fail safe braking requirements.
- Supply harmonics limitations.
- Use of standard / commercial components.
- Whether all drives to be connected to the bus are, or can be, of the same rating.
- The peak current to be drawn from the system in relation to the individual ratings of the drives
- The location of the DC bus softstart/charging circuit within the individual drives.

## 1.2 Advantages and disadvantages of different methods

There are a number of different ways of connecting the drives together and paralleling the DC buses:

- A simple bulk uncontrolled external rectifier - SPMC / SPMU solution.
- AC input and DC bus paralleling.
- 1 host drive supplying DC bus to slave drives.
- Active rectifier (Mentor 4 quadrant controlled rectifier or Unidrive regenerative 4 quadrant PWM converter).

### **Simple bulk uncontrolled external rectifier - SPMC / SPMU solution**

Advantages:

- Allows drives of different ratings to be connected together.
- Reduces AC supply side component sizes.
- Reduces energy losses (heatloss from braking resistors).
- Possible to connect up in 12 pulse configuration to reduce supply harmonics.

Disadvantages:

- Cannot regenerate so dynamic braking may be required.

### **AC input and DC bus paralleled**

Advantages

- No additional rectifier circuit is required.

Disadvantages

- Cannot regenerate so dynamic braking may be required.
- Not possible to connect up in 12 pulse configuration to reduce supply harmonics.
- Only allows drives with same power stage to be connected together.

### **One host drive supplying DC bus to slave drives**

Advantages

- Reduces AC supply side components.
- Host DC bus supply drive controls dynamic braking (if required).
- Allows drives of different ratings to be connected together.

Disadvantages

- Cannot regenerate so dynamic braking may be required.
- Not possible to connect up in 12 pulse configuration to reduce supply harmonics.

### **Active rectifier (Mentor 4 quadrant controlled rectifier or Unidrive regenerative 4 quadrant PWM converter)**

Advantages

- Can regenerate back into the supply.
- Dynamic braking not required.
- Possible to connect Mentor up in 12 pulse configuration to reduce supply harmonics.
- Unidrive PWM converter offers a greater reduction in supply harmonics.
- Allows drives of different ratings to be connected together.

Disadvantage

- Cost and size of adding an extra drive to the system.

### 1.3 Main considerations

#### Inrush current

When drives are connected in parallel the capacitor bank is much larger which increases the inrush current on power up when the capacitors are initially charged.

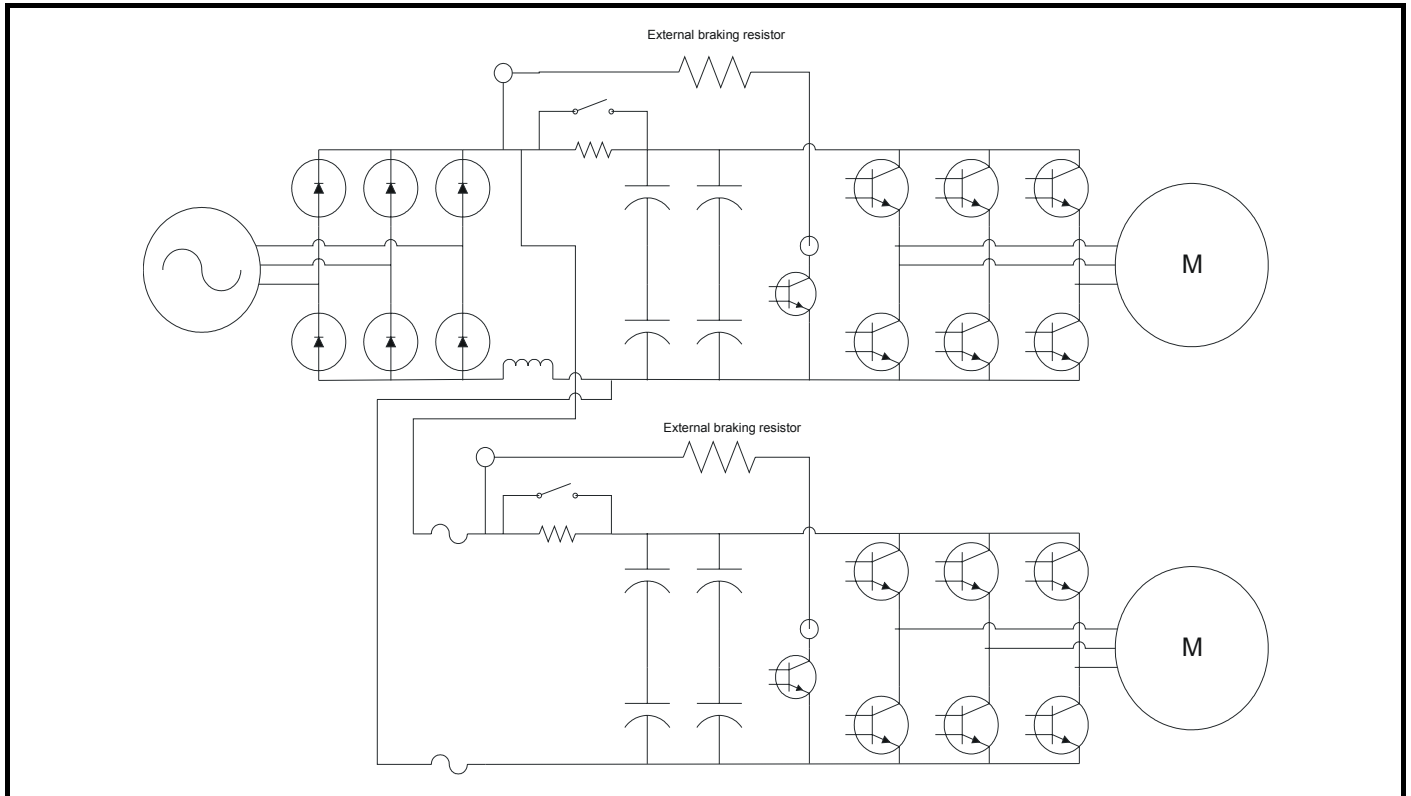
Inrush current is normally controlled using either a resistor / bypass relay circuit or a controlled thyristor bridge which is gradually phased forward.

The input configuration ( including fuses ) must be capable of supplying this inrush current.

Unidrive SP size 1, 2 and 3 have a resistor / bypass relay circuit which is in circuit when the drive is supplied from the AC or the DC terminals.

If an SP size 1,2 or 3 is supplied via the DC terminals only then no additional inrush circuit is required since each drive will limit the inrush current.

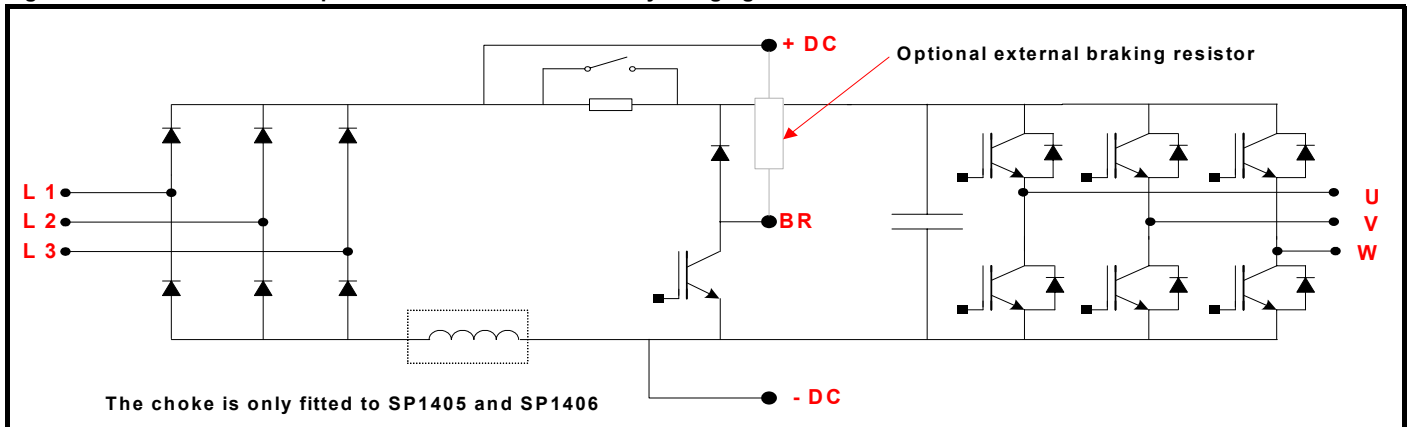
The diagram below shows how the inrush resistor is in circuit on Unidrive SP size 1 to 3 and how the limiting factor with respect to the charging current is only the I2t of the bridge rectifier.



It is not possible to use the inrush circuit to limit the charging current for any other drive due to its location in the circuit - after the DC terminals. If a drive is to be supplied from the DC bus of this drive then it must have its own inrush circuit present in the DC path.

The peak inrush current must be checked to ensure that it does not exceed the peak rating of the power source device or AC supply fuses.

**Figure 1-1 Unidrive SP Size 1 power schematic - resistor / relay charging circuit**



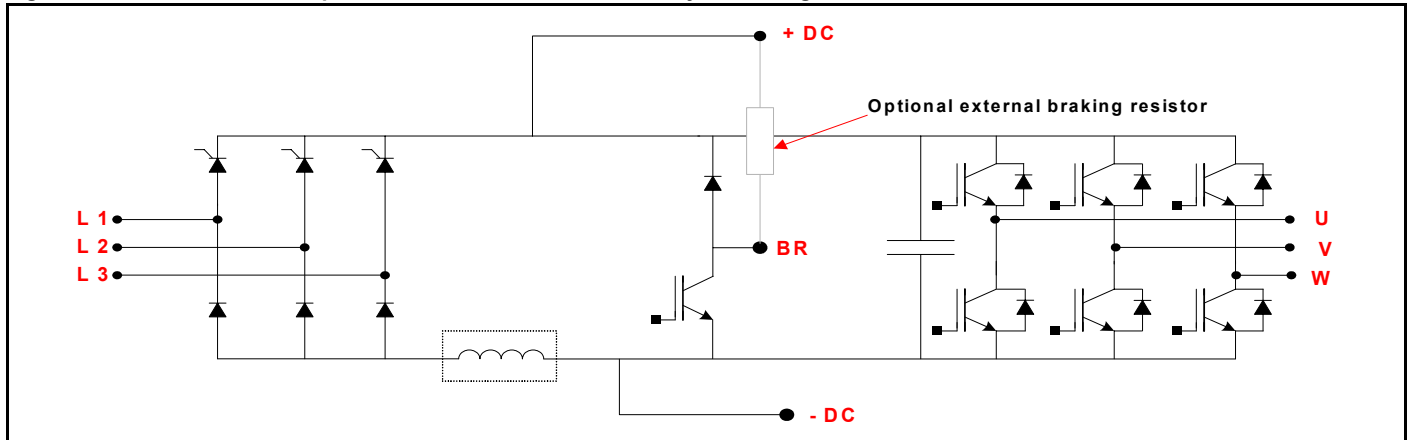
Unidrive SP size 4, 5, 6 and SPMA have a controlled AC thyristor half bridge which only limits the inrush current when the drive is supplied via the AC terminals.

There is no inrush current limitation if the drive is supplied via the DC terminals.

The controlled bridge arrangement limits the inrush current to a low level and can thus typically control the inrush current to more than 1 drive. See Appendix A for DC bus capacitance values of all Unidrive classic and Unidrive SP.

Drive model	Max DC bus capacitance ( uF)
SP size 4	
SP size 5	
SP size 6 / SPMA	

Figure 1-2 Unidrive SP Size 4 power schematic - half controlled thyristor bridge



**Continuous current**

The input must be capable of supplying the highest level of continuous current which will be required by the drives at any point in time.

In the case of an unwind / rewind application the input could be much smaller than the motoring drives since the losses in the system can be quite low compared to the power flowing around the DC circuit. In this case it is common for the AC supply to be connected to one or two drives only with further drives being connected via the DC terminals only.

The duty cycle of each drive must be considered under all possible operating conditions. If both drives can be motoring at the same time the input must be capable of supplying this current.

If the AC supply is connected to more than one drive in a parallel DC bus application the input impedance of the input stage of each drive must be considered.

The input current will be shared in inverse proportion to the difference in input impedance. If different input impedances are present in a system care must be taken to ensure that the input with the lowest input impedance is not overloaded.

In general it is easier to ensure that only drives with the same input impedance are connected to both AC and DC since the current will then be shared equally.

Drives generally have either a DC bus choke or a 3 phase AC line reactor which smoothes the current flowing to the DC capacitors.

In the case of a DC bus choke the most common solution is to fit the reactor in the positive or the negative connection. This the case for Unidrive classic and Unidrive SP sizes 1 to 4.

Otherwise the DC inductance only provides impedance for either the upper diodes or the lower diodes.

In this case a 3 phase line reactor is also required to ensure the upper and lower diodes in the rectifier stage both share current in the correct proportion.

Diodes have a negative temperature coefficient such that the impedance decreases with temperature. Parallel diodes without any series impedance can therefore thermally run away if tolerances result in more current flowing in one diode compared to another.

The diagram below shows that the positive diodes would have no series impedance if AC line reactors were not fitted.

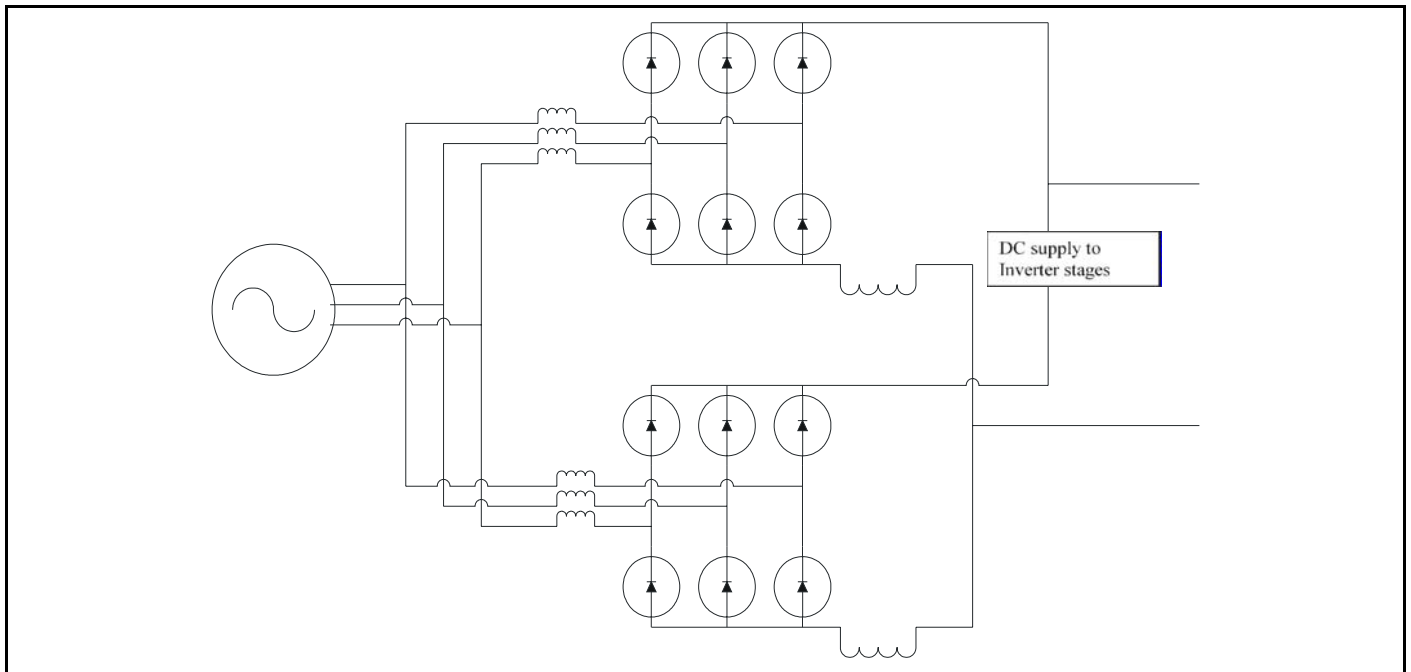
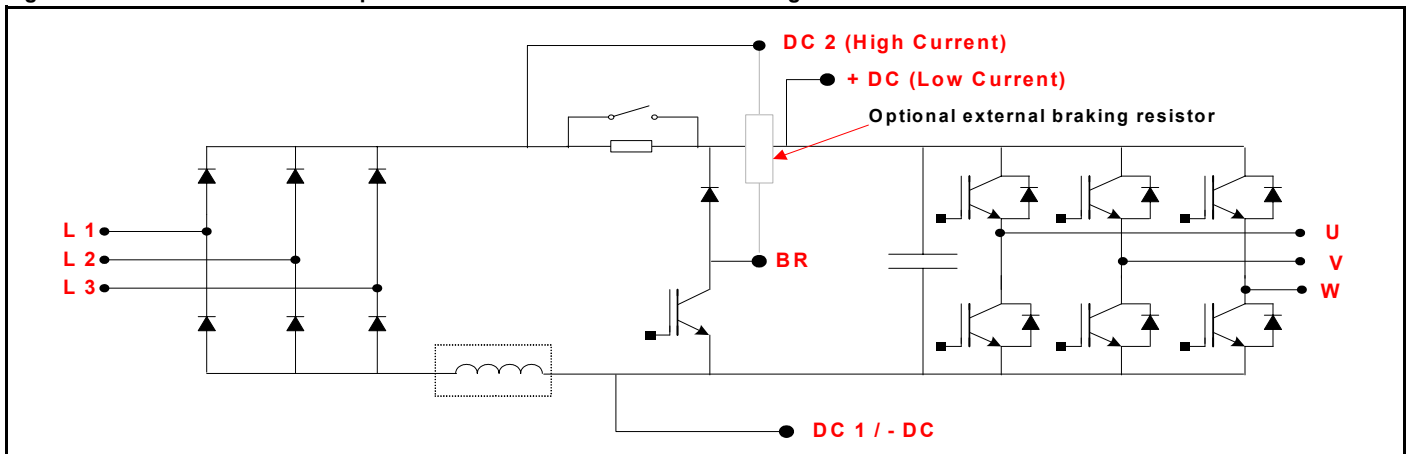
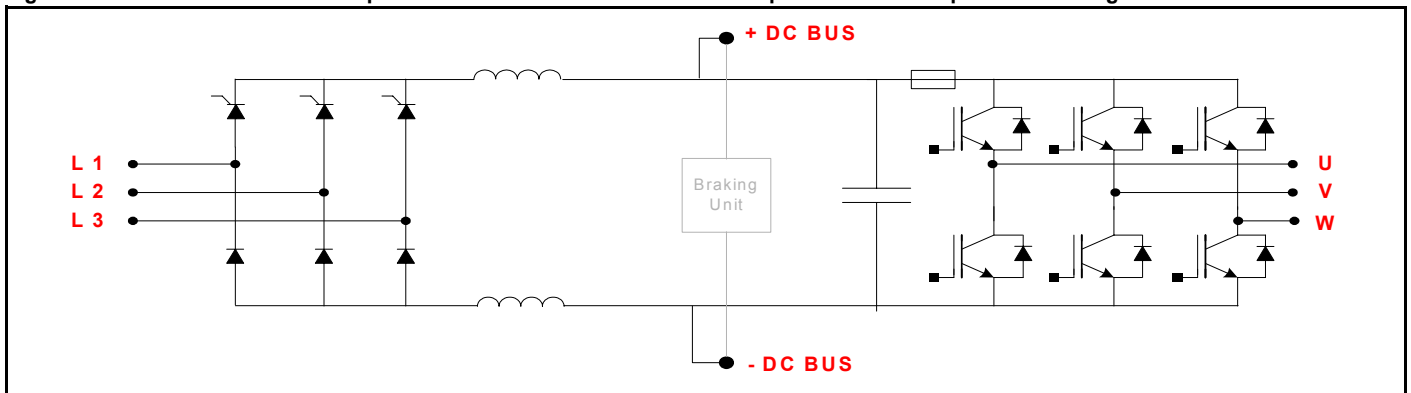


Figure 1-3 Unidrive SP Size 2 & 3 power schematic - DC bus choke in the negative connection.



If the DC bus choke is split such that both positive and negative connections have the same inductance ( as per Unidrive classic size 5 ) then the AC line reactor is not required.

Figure 1-4 Unidrive Classic Size 5 power schematic - DC bus inductance split between both positive and negative connections.



If the system is to consist of many drives of different ratings the best solution is often to use one large common rectifier and supply all drives via DC only.

Alternative solutions to a bridge rectifier ( controlled or uncontrolled ) are a Mentor or a Unidrive in regen mode, both providing a four quadrant solution.

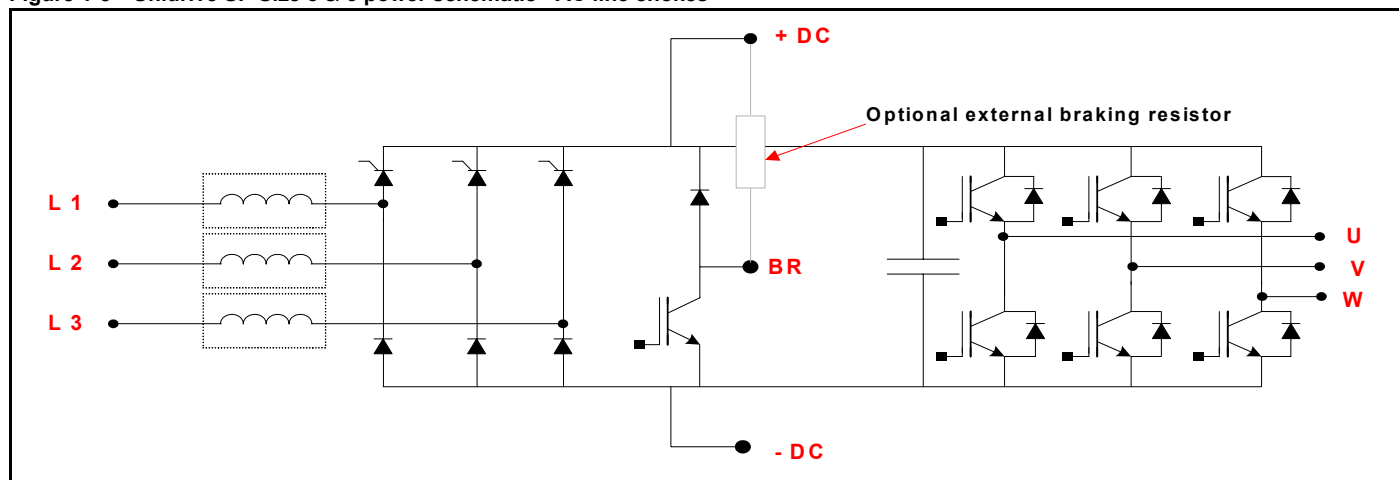
A high voltage Mentor can be used in conjunction with a step up transformer to provide a cost effective solution for regenerating energy back to the AC supply.

Unidrive regen can also be used as a four quadrant solution with the added advantage of very low supply current harmonics due to the sinusoidal current waveform.

For more information see the separate Applications note for the Mentor solution or the Unidrive regen Installation guide.

In the case of a drive with a 3 phase inductor instead of a DC bus choke, as long as the inductances are such that the current will be shared in the correct proportion then no additional component is required. Tolerances in inductance values must be taken into consideration to ensure no single input is overloaded. This is the case for Unidrive SP sizes 5, 6 and SPMA.

**Figure 1-5 Unidrive SP Size 5 & 6 power schematic - AC line chokes**



The power circuits for all Unidrive frame sizes are detailed in Appendix B.

## 1.4 Implementation - Do's and don'ts

Do contact Technical support if you have any doubts / concerns.

## 1.5 Implementation - essential knowledge

### AC and DC to all drives - drives of the same current rating only

The drives should be supplied using a common contactor / isolator to ensure that drives power up at the same time. The inrush current is then shared between the drives on power up.

If drives are powered up sequentially the first drive will charge the whole DC bus which could exceed the peak input current rating for the input of that one drive.

Using a common contactor allows the normal AC fuses to be fitted to each drive as detailed in the user guide.

If the drives have DC bus chokes in one connection only, AC line reactors should be fitted to ensure current is shared in both the upper and lower diodes.

AC line reactor values should be sized such that 2% of the phase voltage is dropped across the reactor. (2% is ok for diode sharing but possibly more for harmonic limitation on stiff supplies).

#### Example

50Hz, 415Vac supply

2% of 240Vac = 4.8V

Drive Input current = 10A

$V = IR$

Voltage drop = Input current x Reactor impedance

$V = I \times 2\pi fL$

$4.8 = 10 \times 2 \times 3.14 \times 50 \times L$

$L = 4.8 / 3140$

$L = 1.5\text{mH} / \text{phase}$

Typical inductor variance is +/-5% depending on the specific inductor.

A derate must therefore be applied to each drive on the system to ensure the currents remain within the limit of each drive input. The derating is equivalent to the maximum variance in the inductor specification which in the case of +/-5% is 10% derating.

Fuses should be fitted in both positive and negative DC connections between drives.

See Appendix C for DC fuse ratings.

It may be possible to connect drives, which are of consecutive ratings together if the input stages are identical. Check the input rectifier device type and the choke inductance.

If they are identical then they can be treated as if they are of the same rating as described above.

### AC and DC to all drives - different current ratings

Only drives with the same input stage type should be connected with AC and DC connections, i.e. Systems consisting of all SP size 1 to 3 (resistor / relay) or systems consisting of SP size 4 and higher (thyristor controlled bridge).

SP size 1 drives without DC chokes cannot be mixed with other drives but can be mixed together.

A mix of drives is not possible due to the different delays in soft start associated with the two circuits. Other solutions for these systems must be used.

### SP size 1 to 3 solutions

A common contactor must be used to power all drives up simultaneously.

Inrush current through one rectifier is no longer an issue since all drives will power up through their own charging circuit.

AC chokes must be fitted to each drive in proportion to the input current of that drive.

A derating of 10% must be applied to all drives in the system to take into account tolerances in the line reactor values to ensure no input can be overloaded.

The derating must be applied to all drives since the inverter input and output stages are commoned at the DC bus.

Any values in the correct ratio will cause the current to be shared correctly.

Values which are too high will result in excessive voltage drop.

Any deviation from the ideal values should be applied in the form of a derating to all drives.

The percentage deviation should be applied as a percentage derating.

AC supply to one drive, supplying other drives via the DC bus

The AC supply is usually connected to the largest drive in the system.

The largest drive is sometimes increased in size to ensure the input is not overloaded.

One or more smaller drives are fed from the DC bus terminals of the larger drive.

The total inrush current to the secondary drives must not cause the peak current to exceed the maximum capability of the larger drive.

**Table 1-1 Unidrive SP peak inrush current values on first power up ( brownout can be higher - up to 10 times bigger ).**

Drive model	Peak inrush current
SP120X	18
SP140X	35
SP220X	12
SP240X	24
SP320X	8
SP340X	14
SP350X	18
SP420X	73
SP4401	37
SP4402, SP4403	73
SP460X	35
SP540X	110
SP560X	70

If the system consists of SP sizes 1 to 3 only, the inrush current is limited in each drive by it's own resistor / relay circuit. The total inrush current must still be checked to ensure it remains within the I2t limit of the bridge rectifier on the drive connected to the AC supply.

If the system consists of SP size 4 and higher then the maximum DC bus capacitance which the rectifier can supply must be checked against the values below.

**Table 1-2 Maximum DC bus capacitance charging capability for SP size 4,5 and 6**

Drive model	Max DC bus capacitance ( total ) ( mF )
SP4201	36.5
SP4202	
SP4203	
SP4401	9.13
SP4402	
SP4403	
SP4601	2.34
SP4602	
SP4603	
SP4604	
SP4605	
SP4606	
SP5401	51
SP5402	
SP5601	6.3
SP5602	
SP6401	33.65
SP6402	
SP6601	8.7
SP6602	
SPMC1401*	44 (INL402)
SPMC1402*	66 (INL402)
SPMC2402*	2 x 66 (2 x INL402)
SPMC1601*	29.3 (INL602)
SPMC2601*	2 x 29.3 (2 x INL602)
SPMA1401	33.65
SPMA1402	
SPMA1601	8.7
SPMA1602	

\*The input line reactor is required to attain these ratings is shown in brackets.

If the system consists of a mix of drives the peak inrush current must be calculated and must not exceed the values given below for the single drive connected to the AC supply.

In order to ensure the rectifier can withstand the inrush current the rectifier I2t must be checked using the following equation :

$$\text{Rectifier I2t} > (2/3 \times \text{peak inrush current})^2 \times 10\text{ms}$$

For all of the above solutions the AC fuses to the drive connected to the AC supply must be chosen to ensure no spurious fuse failures occur.

For SP size 4 and upwards the fuses in the user guide are suitable for this type of application without any changes required as they have been chosen for worst case supply brownout conditions.

Unidrive SP sizes 1 to 3 should use gG fuse option as given in the User guide. gG fuses are rated for motor start applications thus will withstand increased inrush current.

DC fuses should be connected to both negative and positive connections.

See Appendix for DC fuse ratings.

**Use of a single rectifier, DC to all drives**

The rectifier must be chosen such that it can supply the highest motoring current required based on the sum of the duty cycles of all drives on the system.

DC bus current calculation -

Use large drive power and current rating to choose rectifier.

The SPMC (controlled rectifier) module is an ideal candidate for such an application as a pre engineered solution.

See the Applications Note for using the SPMC as a stand alone rectifier.

## 1.6 Examples

### Example 1

Winder / unwinder sharing energy via the DC bus.

Both drives are SP3401

Checking the schematic the SP3401 has a diode bridge with resistor / relay inrush circuit.

The inrush resistor is in circuit when supplied via the DC bus.

There are 2 possible solutions :

A ) Connect the AC supply to one drive and supply the other from DC only.

B ) Connect both drives to the AC and DC supplies.

The cheapest would be option A since less cabling and fuses are required.

Inrush current limitation

Both drives will have their individual inrush resistors in circuit.

Only check required is that charging current does not exceed  $I_{2t}$  of the bridge rectifier.

Inrush current of SP3401 is 14A

Since drive is rated at 34A then no issue.

Continuous current

Since in a winder / unwinder application one drive is always regenerating the majority of the current circulates around the DC connections.

See the picture at the start of this application note.

The AC connection is only required to supply current for the losses in the system.

Losses which must be supplied are drive losses, motor losses and, mechanical friction and windage losses. In general these will be quite small in comparison to the drive rating and thus the continuous input current to the one drive is much smaller than the rating of one drive.

If there is any doubt, a measurement should be taken to ensure that the current remains below the typical value given in the manual.

Fuses must be fitted in both DC connections as given in Appendix C.

### Example 2

4 x SP4401 all connected using AC and DC connections

Reason for paralleling is to share 1 braking resistor between all 4 drives.

All drives are required to run at full load at the same time.

Checking the power schematic - SP size 4 has a controlled thyristor input stage and a DC choke in the negative connection.

Since the drives are all required to run at full load there are two possible solutions :

A) Supply all drives using AC and DC connections.

B) Supply all drives with DC only from a separate device - rectifier module / SP in regen mode or Mentor.

Option A is the cheapest solution since no extra devices are required.

Inrush current check.

Check DC capacitance of an SP size 4 = 1100uF

Total capacitance = 4,400uF

Check max capacitance which can be charged from 1 SP4401 = XuF

Since the max value is higher than 4,440uF drive can have individual contactors if required. (A single contactor is not required for simultaneous application of power).

It should be noted that all 4 drives will be powered up at the same time through the individual input.

The cheaper option of one single contactor or individual contactors may be used however the system must not be allowed to run unless all contactors are closed.

If any one contactor fails to close then the other 3 inputs could be overloaded once the run command is given. It is recommended that

auxiliary connections are used to provide feedback that that all contactors are closed.

Continuous current check.

Since the SP size 4 has a DC bus choke in the negative connection AC line chokes are required to ensure the current is shared in the positive diodes.

Calculate AC line choke based on 2% voltage drop for SP4401

50Hz, 415Vac supply

2% of 240Vac = 4.8V

Drive Input current = 61.2A (from User guide)

$V = IR$

Voltage drop = Input current x Reactor impedance

$V = I \times 2\pi fL$

$4.8 = 61.2 \times 2 \times 3.14 \times 50 \times L$

$L = 4.8 / 314 \times 61.2$

$L = 249\mu H / \text{phase}$

### Example 3

SP1405, SP2402, SP3403 connected AC and DC in parallel to share regenerative energy and one braking resistor for E stop.

Input currents

SP1405 10A

SP2403 26.6A

SP3403 51.3A

Choose 2% line reactance for each drive will select the correct inductance values such that each input supplies the correct level of current.

50Hz, 415Vac supply

2% of 240Vac = 4.8V

$V = IR$

Voltage drop = Input current x Reactor impedance

$V = I \times 2\pi fL$

#### SP1405

$4.8 = 10 \times 2 \times 3.14 \times 50 \times L$

$L = 4.8 / 3140$

$L = 1.5\text{mH} / \text{phase}$

#### SP2403

$4.8 = 26.6 \times 2 \times 3.14 \times 50 \times L$

$L = 4.8 / 314 \times 1$

$L = 574\mu H / \text{phase}$

#### SP3403

$4.8 = 51.3 \times 2 \times 3.14 \times 50 \times L$

$L = 4.8 / 314 \times 1$

$L = 297\mu H / \text{phase}$

If the exact values are not available then select similar inductance values in the inverse ratio of the current values.

i.e.

Input I	/I0	Inductance (mH)
10	1	2.66
26.6	2.66	1
51.3	5.13	0.52*

\*Divide 2.66 / 5.13 to get this value.

DC fusing of values given in Appendix C should be fitted in both positive and negative connections.

AC fuses can be as for normal individual drive installation.

**Example 4**

System consists of 1 x SP1406, 4 x SP2402, 2 x SP3401, 1 x SP5401

Requirement to have a common DC bus to share a braking resistor.

Machine operates under the following conditions :

SP5401 operates all of the time

SP1406 + 4 x SP2402 operate or 2 x SP3401 operate

Checking the power schematics, SP sizes 1 to 3 all have diode bridges with resistor relay inrush control. SP size 5 has a thyristor front end.

It is not possible to connect AC and DC to all drives since the controlled rectifier on the SP size 4 will take longer to power up than the diode bridges on the other drives.

The total DC bus capacitance of the system is :

$$1 \times 1406 = 410\mu\text{F}$$

$$4 \times 2402 = 4 \times 705\mu\text{F} = 2,820\mu\text{F}$$

$$2 \times 3402 = 2 \times 1350\mu\text{F} = 2,700\mu\text{F}$$

$$1 \times 5401 = 3,300\mu\text{F}$$

$$\text{Total} = 9,230\mu\text{F}$$

Max charging capability of an SP5401 is 51mF.

< not relevant since resistors in circuit >

SP5401 has the same input stage as an SP5402 . SP size 5 is rated as follows :

SP5401 = 75kW (normal duty) or 55kW (heavy duty)

SP5402 = 90kW (normal duty) or 75kW (heavy duty)

Thus, the SP size 5 drive input stage can supply 90kW on a continuous basis.

SP5401 has been chosen in heavy duty mode since high overload is required for start up only.

If the drives can be started sequentially such that any overload required to start the machine does not add up then the maximum continuous load on the input stage at any point in time is :

SP5401 - 55kW

SP1406 - 4kW

4 x SP2402 - 4 x 7.5kW

Total motoring power = 89kW

or

SP5401 - 55kW

2 x SP3401 - 2 x 15kW

Total motoring power = 85kW

Therefore solution of SP5401 supplied via AC with all other drives supplied via the DC bus is ok.

DC fusing is required as detailed in Appendix C.

## 1.7 Appendix: Unidrive SP and Unidrive classic DC bus capacitance values

### 1.7.1 Unidrive SP - DC Bus Capacitance & Inductance

#### Unidrive SP Size 1

Voltage	Model	Power Rating	Total D.C. Bus Capacitance	Total D.C. Bus Inductance
200V	1201	0.75/1.1kW	940µF (2 x 470µF) (1664-3487)	No Choke Fitted
200V	1202	1.1/1.5kW	940µF (2 x 470µF) (1664-3487)	No Choke Fitted
200V	1203	1.5/2.2kW	1640µF (2 x 820µF) (1664-3425)	No Choke Fitted
200V	1204	2.2/3.0kW	1640µF (2 x 820µF) (1664-3425)	No Choke Fitted
400V	1401	0.75/1.1 kW	235µF (2 x 470µF) (1664-3487)	No Choke Fitted
400V	1402	1.1/1.5 kW	235µF (2 x 470µF) (1664-3487)	No Choke Fitted
400V	1403	1.5/2.2 kW	235µF (2 x 470µF) (1664-3487)	No Choke Fitted
400V	1404	2.2/3.0 kW	410µF (2 x 820µF) (1664-3425)	No Choke Fitted
400V	1405	3.0/4.0 kW	410µF (2 x 820µF) (1664-3425)	1.25mH (4400-0234)
400V	1406	4.0/5.5 kW	410µF (2 x 820µF) (1664-3425)	1.25mH (4400-0234)

#### Unidrive SP Size 2

Voltage	Model	Power Rating	Total D.C. Bus Capacitance	Total D.C. Bus Inductance
200V	2201	3.0/4.0kW	2820µF (6 x 470µF) (1664-3487)	1.4mH (4400-0014)
200V	2202	4.0/5.5kW	2820µF (6 x 470µF) (1664-3487)	1.4mH (4400-0014)
200V	2203	5.5/7.5kW	2820µF (6 x 470µF) (1664-3487)	1.4mH (4400-0014)
400V	2401	5.5/7.5kW	705µF (6 x 470µF) (1664-3487)	1.4mH (4400-0014)
400V	2402	7.5/11.0kW	705µF (6 x 470µF) (1664-3487)	1.4mH (4400-0014)
400V	2403	11.0/15.0kW	705µF (6 x 470µF) (1664-3487)	1.4mH (4400-0014)
400V	2404	15.0kW	705µF (6 x 470µF) (1664-3487)	1.4mH (4400-0014)

#### Unidrive SP Size 3

Voltage	Model	Power Rating	Total D.C. Bus Capacitance	Total D.C. Bus Inductance
200V	3201	7.5/11.0kW	5400µF (2 x 2700µF) (1672-4275)	0.7mH (2 x 1.4mH) (4400-0014)
200V	3202	11.0/15.0kW	5400µF (2 x 2700µF) (1672-4275)	0.7mH (2 x 1.4mH) (4400-0014)
400V	3401	15.0/18.5kW	1350µF (2 x 2700µF) (1672-4275)	0.7mH (2 x 1.4mH) (4400-0014)
400V	3402	18.5/22.0kW	1350µF (2 x 2700µF) (1672-4275)	0.7mH (2 x 1.4mH) (4400-0014)
400V	3403	22.0/30.0kW	1350µF (2 x 2700µF) (1672-4275)	0.7mH (2 x 1.4mH) (4400-0014)
575V	3501	2.2/3.0kW	1000µF (2 x 2000µF) (1673-4205)	4mH (2 x 8mH) (4400-0015)
575V	3502	3.0/4.0kW	1000µF (2 x 2000µF) (1673-4205)	4mH (2 x 8mH) (4400-0015)
575V	3503	4.0/5.5kW	1000µF (2 x 2000µF) (1673-4205)	4mH (2 x 8mH) (4400-0015)
575V	3504	5.5/7.5kW	1000µF (2 x 2000µF) (1673-4205)	4mH (2 x 8mH) (4400-0015)
575V	3505	7.5/11.0kW	1000µF (2 x 2000µF) (1673-4205)	4mH (2 x 8mH) (4400-0015)
575V	3506	11.0/15.0kW	1000µF (2 x 2000µF) (1673-4205)	4mH (2 x 8mH) (4400-0015)
575V	3507	15.0/18.5kW	1000µF (2 x 2000µF) (1673-4205)	4mH (2 x 8mH) (4400-0015)

#### Unidrive SP size 4

Voltage	Model	Power Rating	Total D.C. Bus Capacitance	Total D.C. Bus Inductance
200V	4201	15/18.5kW	4400µF (2 x 2,200µF) (1664-4228-01)	0.211mH (4400-0017-00)
200V	4202	18.5/22kW	4400µF (2 x 2,200µF) (1664-4228-01)	0.211mH (4400-0017-00)
200V	4203	22/30kW	4400µF (2 x 2,200µF) (1664-4228-01)	0.211mH (4400-0017-00)
400V	4401	30/37kW	1100µF (2 x 2,200µF) (1664-4228-01)	0.85mH (4400-0019-00)
400V	4402	37/45kW	2200µF (4 x 2,200µF) (1664-4228-01)	0.423mH (4400-0020-00)
400V	4403	45/55kW	2200µF (4 x 2,200µF) (1664-4228-01)	0.423mH (4400-0020-00)
690V	4601	15/18.5kW	733µF (3 x 2,200µF) (1664-4228-01)	1.27mH (4400-0018-00)
690V	4602	18.5/22kW	733µF (3 x 2,200µF) (1664-4228-01)	1.27mH (4400-0018-00)
690V	4603	22/30kW	733µF (3 x 2,200µF) (1664-4228-01)	1.27mH (4400-0018-00)
690V	4604	30/37kW	733µF (3 x 2,200µF) (1664-4228-01)	1.27mH (4400-0018-00)
690V	4605	37/45kW	733µF (3 x 2,200µF) (1664-4228-01)	1.27mH (4400-0018-00)
690V	4606	45/55kW	733µF (3 x 2,200µF) (1664-4228-01)	1.27mH (4400-0018-00)

### 1.7.2 Unidrive SP size 5 and 6 use AC line chokes instead of DC bus chokes

#### Unidrive SP size 5

Voltage	Model	Power Rating	Total D.C. Bus Capacitance	AC line Inductance per phase
400V	5401	55/75kW	3300 $\mu$ F (6 x 2,200 $\mu$ F) (1664-4228-01)	0.150mH (4400-0040-00)
400V	5402	75/90kW	3300 $\mu$ F (6 x 2,200 $\mu$ F) (1664-4228-01)	0.150mH (4400-0040-00)
690V	5601	55/75kW	1467 $\mu$ F (6 x 2,200 $\mu$ F) (1664-4228-01)	0.470mH (4400-0041-00)
690V	5602	75/90kW	1467 $\mu$ F (6 x 2,200 $\mu$ F) (1664-4228-01)	0.470mH (4400-0041-00)

#### Unidrive SP size 6

Voltage	Model	Power Rating	Total D.C. Bus Capacitance	AC line Inductance per phase
400V	6401	90/110kW	4400 $\mu$ F (8 x 2,200 $\mu$ F) (1664-4228-01)	L1, 0.054mH (4400-0033-00) L2, 0.054mH (4400-0034-00) L3, 0.054mH (4400-0035-00)
400V	6402	110/132kW	5500 $\mu$ F (10 x 2,200 $\mu$ F) (1664-4228-01)	L1, 0.054mH (4400-0033-00) L2, 0.054mH (4400-0034-00) L3, 0.054mH (4400-0035-00)
690V	6601	75/90kW	2200 $\mu$ F (9 x 2,200 $\mu$ F) (1664-4228-01)	L1, 0.313mH (4400-0036-00) L2, 0.313mH (4400-0037-00) L3, 0.313mH (4400-0038-00)
690V	6602	90/110kW	2200 $\mu$ F (9 x 2,200 $\mu$ F) (1664-4228-01)	L1, 0.313mH (4400-0036-00) L2, 0.313mH (4400-0037-00) L3, 0.313mH (4400-0038-00)

#### Unidrive SPMA

Voltage	Model	Power Rating	Total D.C. Bus Capacitance	AC line Inductance per phase
400V	1401	90/110kW	4400 $\mu$ F (8 x 2,200 $\mu$ F) (1664-4228-01)	L1, 0.054mH (4400-0033-00) L2, 0.054mH (4400-0034-00) L3, 0.054mH (4400-0035-00)
400V	1402	110/132kW	5500 $\mu$ F (10 x 2,200 $\mu$ F) (1664-4228-01)	L1, 0.054mH (4400-0033-00) L2, 0.054mH (4400-0034-00) L3, 0.054mH (4400-0035-00)
690V	1601	75/90kW	2200 $\mu$ F (9 x 2,200 $\mu$ F) (1664-4228-01)	L1, 0.313mH (4400-0036-00) L2, 0.313mH (4400-0037-00) L3, 0.313mH (4400-0038-00)
690V	1602	90/110kW	2200 $\mu$ F (9 x 2,200 $\mu$ F) (1664-4228-01)	L1, 0.313mH (4400-0036-00) L2, 0.313mH (4400-0037-00) L3, 0.313mH (4400-0038-00)

### 1.7.3 Unidrive SPMD have no AC line or DC bus chokes fitted – DC fed inverter module

#### Unidrive SPMD

Voltage	Model	Power Rating	Total D.C. Bus Capacitance
400V	1401	90/110kW	4400 $\mu$ F (8 x 2,200 $\mu$ F) (1664-4228-01)
400V	1402	110/132kW	5500 $\mu$ F (10 x 2,200 $\mu$ F) (1664-4228-01)
400V	1403	132/160kW	6600 $\mu$ F (12 x 2,200 $\mu$ F) (1664-4228-01)
400V	1404	160/185kW	6600 $\mu$ F (12 x 2,200 $\mu$ F) (1664-4228-01)
690V	1601	75/90kW	2200 $\mu$ F (9 x 2,200 $\mu$ F) (1664-4228-01)
690V	1602	90/110kW	2200 $\mu$ F (9 x 2,200 $\mu$ F) (1664-4228-01)
690V	1603	110/132kW	2933 $\mu$ F (12 x 2,200 $\mu$ F) (1664-4228-01)
690V	1604	132/160kW	2933 $\mu$ F (12 x 2,200 $\mu$ F) (1664-4228-01)

## 1.7.4 Unidrive - DC Bus Capacitance & Inductance

### Unidrive Size 1

Voltage	Model	Power Rating	Total D.C. Bus Capacitance	Total D.C. Bus Inductance
200V	1201	0.37kW	1300 $\mu$ F (2 x 2600 $\mu$ F) (1662-4265)	No Choke Fitted
200V	1202	0.55kW	1300 $\mu$ F (2 x 2600 $\mu$ F) (1662-4265)	No Choke Fitted
200V	1203	0.75kW	1300 $\mu$ F (2 x 2600 $\mu$ F) (1662-4265)	No Choke Fitted
200V	1204	1.1kW	1300 $\mu$ F (2 x 2600 $\mu$ F) (1662-4265)	No Choke Fitted
200V	1205	2.2kW	1300 $\mu$ F (2 x 2600 $\mu$ F) (1662-4265)	1.5mH (4400-0100)
400V	1401	0.75kW	235 $\mu$ F (2 x 470 $\mu$ F) (1664-3487)	No Choke Fitted
400V	1402	1.1kW	235 $\mu$ F (2 x 470 $\mu$ F) (1664-3487)	No Choke Fitted
400V	1403	1.5kW	235 $\mu$ F (2 x 470 $\mu$ F) (1664-3487)	No Choke Fitted
400V	1404	2.2kW	235 $\mu$ F (2 x 470 $\mu$ F) (1664-3487)	No Choke Fitted
400V	1405	4kW	340 $\mu$ F (2 x 680 $\mu$ F) (1664-3685)	1.5mH (4400-0100)

### Unidrive Size 2

Voltage	Model	Power Rating	Total D.C. Bus Capacitance	Total D.C. Bus Inductance
200V	2201	3kW	2600 $\mu$ F (4 x 2600 $\mu$ F) (1662-4265)	1.7mH, 16A (4400-0101)
200V	2202	4kW	2600 $\mu$ F (4 x 2600 $\mu$ F) (1662-4265)	1.7mH, 16A (4400-0101)
200V	2203	5.5kW	2600 $\mu$ F (4 x 2600 $\mu$ F) (1662-4265)	1.2mH, 25A (4400-1101)
400V	2401	5.5kW	470 $\mu$ F (4 x 470 $\mu$ F) (1664-3473)	1.7mH, 16A (4400-0101)
400V	2402	7.5kW	470 $\mu$ F (4 x 470 $\mu$ F) (1664-3473)	1.7mH, 16A (4400-0101)
400V	2403	11kW	680 $\mu$ F (4 x 680 $\mu$ F) (1664-3685)	1.2mH, 25A (4400-1101)

### Unidrive Size 3

Voltage	Model	Power Rating	Total D.C. Bus Capacitance	Total D.C. Bus Inductance
200V	3201	7.5kW	7500 $\mu$ F (2 x 15000 $\mu$ F) (1662-5155)	1.7mH, 34A (4400-0079)
200V	3202	11kW	7500 $\mu$ F (2 x 15000 $\mu$ F) (1662-5155)	0.8mH, 46A (4400-0081)
200V	3203	15kW	7500 $\mu$ F (2 x 15000 $\mu$ F) (1662-5155)	0.9mH, 60A (4400-1082)
200V	3204	22kW	7500 $\mu$ F (2 x 15000 $\mu$ F) (1662-5155)	0.6mH, 74A (4400-0053)
400V	3401	15kW	1100 $\mu$ F (2 x 2200 $\mu$ F) (1665-4220)	1.7mH, 34A (4400-0079)
400V	3402	18.5kW	1100 $\mu$ F (2 x 2200 $\mu$ F) (1665-4220)	1.9mH, 40A (4400-0080)
400V	3403	22kW	2200 $\mu$ F (2 x 4400 $\mu$ F) (1665-4440)	0.8mH, 46A (4400-0081)
400V	3404	30kW	2200 $\mu$ F (2 x 4400 $\mu$ F) (1665-4440)	0.9mH, 60A (4400-1082)
400V	3405	37kW	2200 $\mu$ F (2 x 4400 $\mu$ F) (1665-4440)	0.6mH, 74A (4400-0053)

### Unidrive Size 4

Voltage	Model	Power Rating	Total D.C. Bus Capacitance	Total D.C. Bus Inductance
400V	4401	45kW	3300 $\mu$ F (6 x 2200 $\mu$ F) (1665-4220)	0.58mH, 96A (4400-0085)
400V	4402	55kW	4400 $\mu$ F (4 x 4400 $\mu$ F) (1665-4440)	0.51mH, 156A (4400-0087)
400V	4403	75kW	4400 $\mu$ F (4 x 4400 $\mu$ F) (1665-4440)	0.51mH, 156A (4400-0087)
400V	4404	90kW	6600 $\mu$ F (6 x 4400 $\mu$ F) (1665-4440)	0.25mH, 220A (4400-1089)
400V	4405	110kW	6600 $\mu$ F (6 x 4400 $\mu$ F) (1665-4440)	0.25mH, 220A (4400-1089)

### Unidrive Size 5

Voltage	Model	Power Rating	Total D.C. Bus Capacitance	Total D.C. Bus Inductance
400V	5401	160kW	8800 $\mu$ F (8 x 4400 $\mu$ F) (1664-4445)	0.2mH (4325-0061)

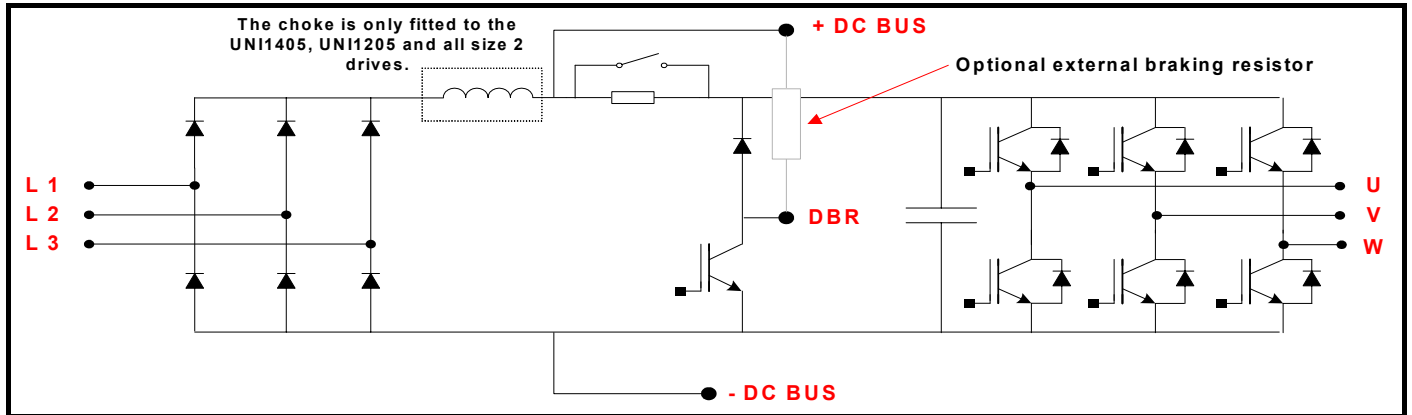
## 1.8 Appendix: Unidrive SP and Unidrive classic power schematics

### 1.8.1 Details the power connections for all sizes of Unidrive Classic and SP

#### Unidrive Classic

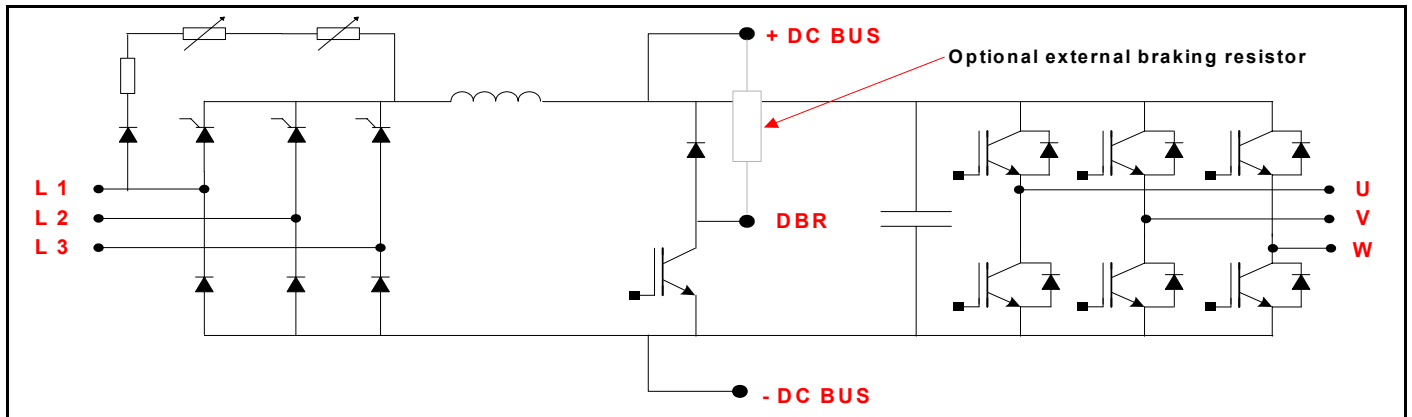
The diagrams below are labelled as per the drive terminals.

Figure 1-6 Unidrive Classic Size 1 & 2



The external braking resistor is fitted across the + DC BUS and DBR terminals.

Figure 1-7 Unidrive Classic Size 3 & 4

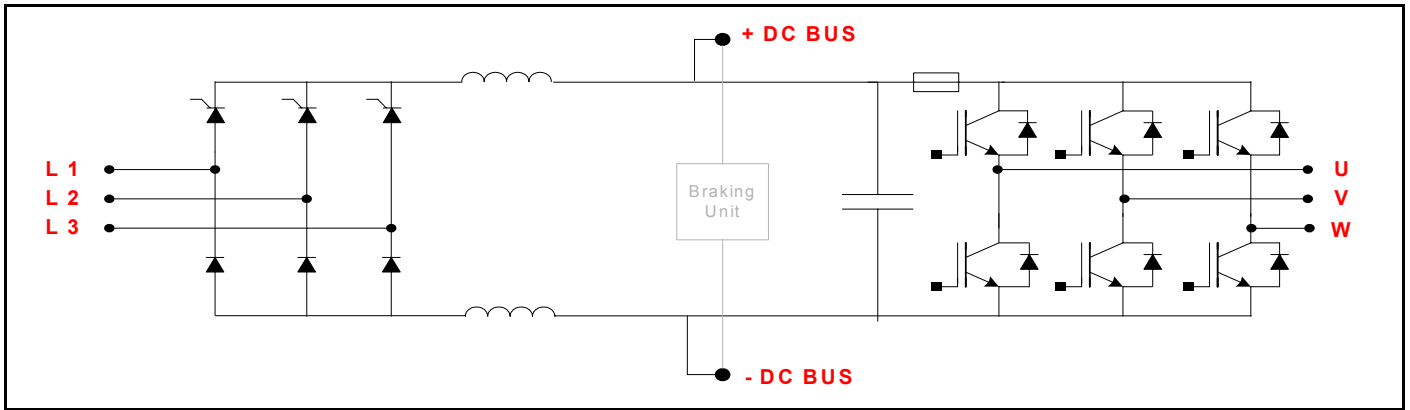


The external braking resistor is fitted across the + DC BUS and DBR terminals.

Table 1-3 Terminal Connections (Unidrive Classic Sizes 1 to 4)

Drive Terminals	Diagram Label
L 1	L 1
L 2	L 2
L 3	L 3
U	U
V	V
W	W
+	+ DC BUS
•	DBR
-	- DC BUS

Figure 1-8 Unidrive Classic Size 5



The braking unit for size 5 is an external option. This is connected across the + DC and - DC terminals, with a control ribbon connecting to the IN96.

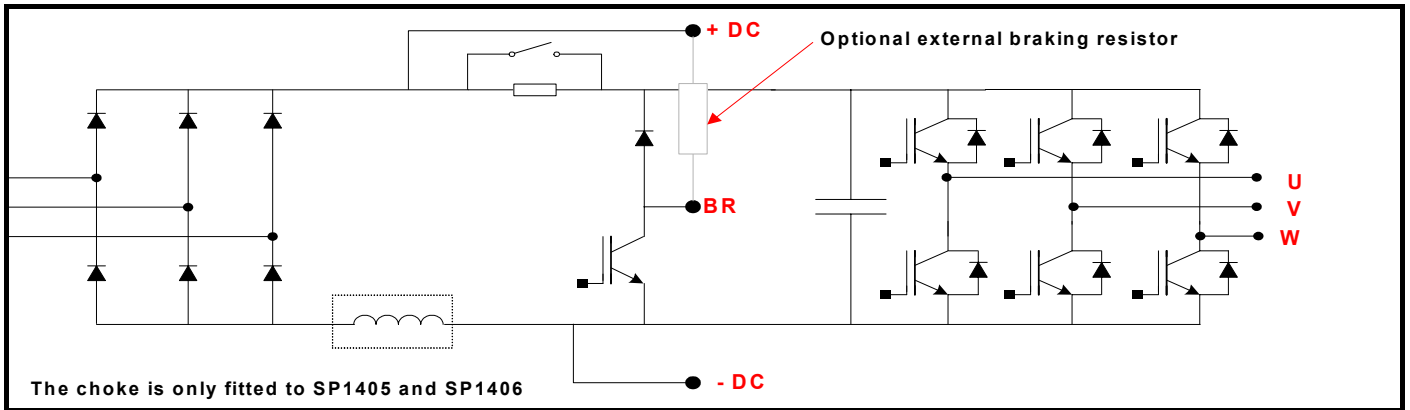
**Unidrive SP**

The diagrams below are labelled as per the drive terminals.

The internal EMC filter is fitted across the + DC and earth terminal.

Low Voltage DC Operation Connections - see Unidrive SP Low Voltage DC Operation application note.

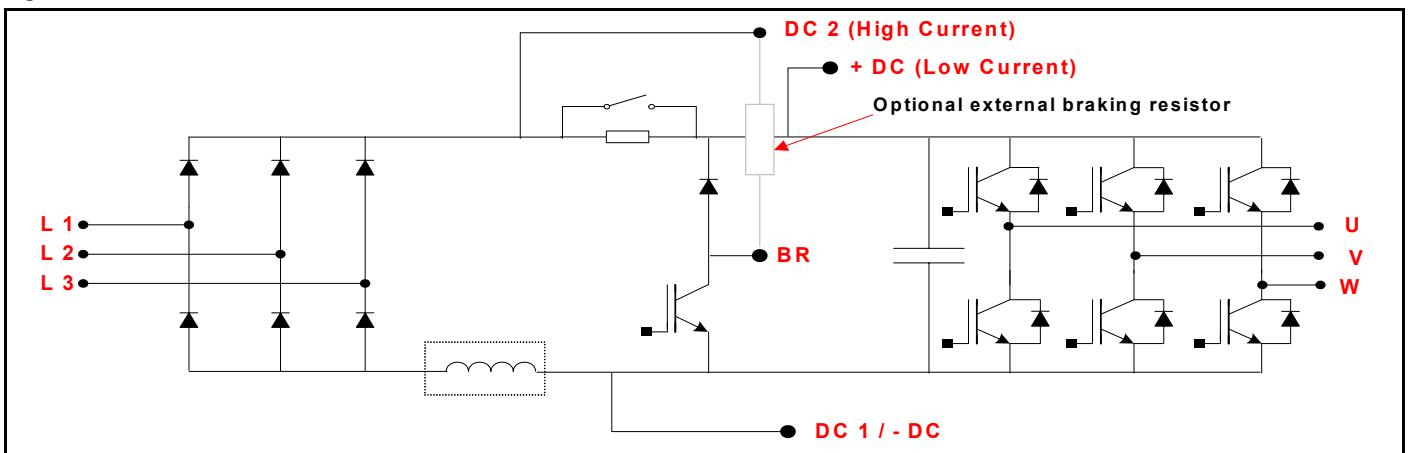
Figure 1-9 Unidrive SP Size 1



The choke is only fitted to SP1405 and SP1406

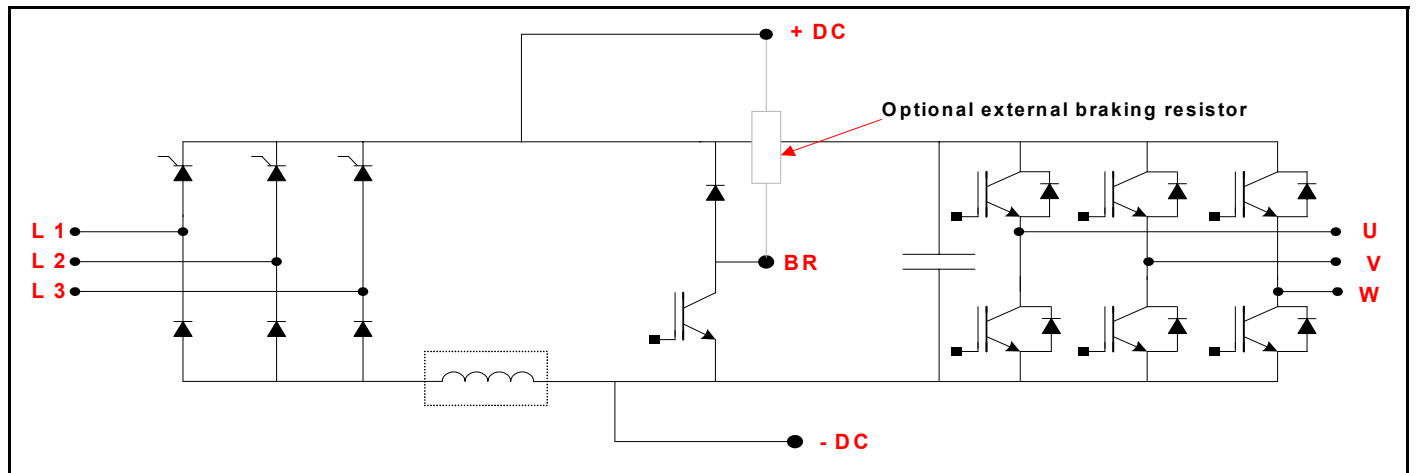
The external braking resistor is fitted across the + DC and BR terminals.

Figure 1-10 Unidrive SP Size 2 & 3



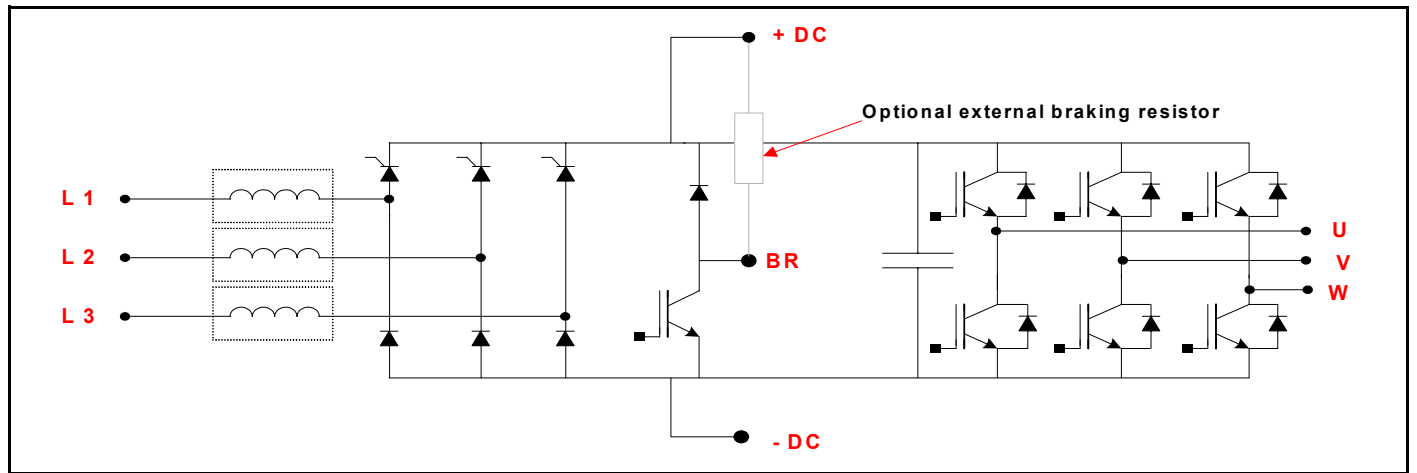
The external braking resistor is fitted across the DC2 and BR terminals.

Figure 1-11 Unidrive SP Size 4



The external braking resistor is fitted across the +DC and BR terminals.

Figure 1-12 Unidrive SP Size 5 & 6



The external braking resistor is fitted across the +DC and BR terminals.

**Unidrive SPM**

The diagrams below are labelled as per the drive terminals.

The internal EMC filter is fitted across the + DC and earth terminal.

Low Voltage DC Operation Connections - see Unidrive SP Low Voltage DC Operation application note.

Figure 1-13

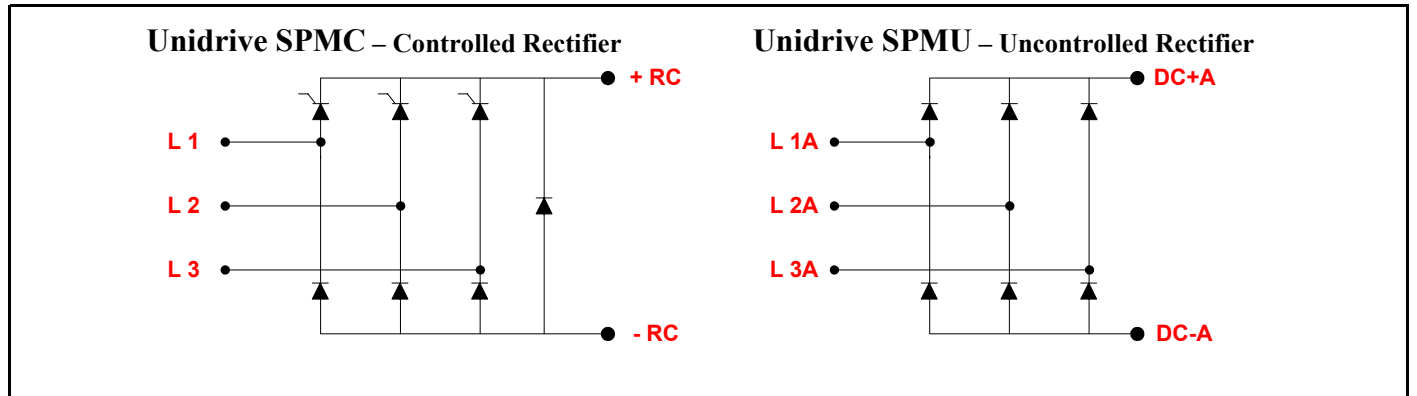
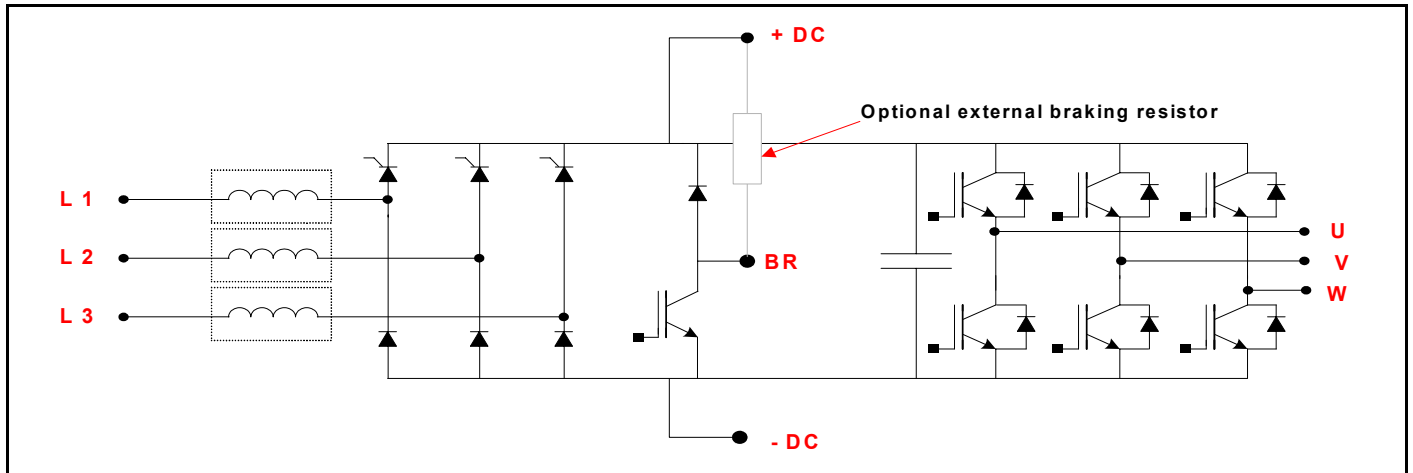
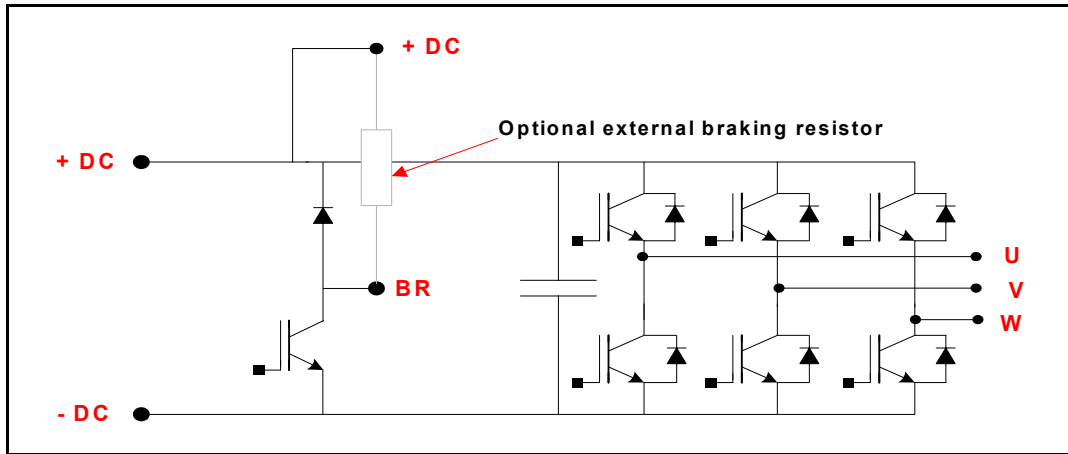


Figure 1-14 Unidrive SPMA - AC to AC Inverter



The external braking resistor is fitted across the +DC and BR terminals.

Figure 1-15 Unidrive SPMD - DC to AC Inverter



The external braking resistor is fitted across the +DC and BR terminals.

## 1.9 Appendix: DC Fuse values

DC supplied drive. Supply connected to -DC and +DC terminals.

Model	Volts DC	Amps DC	R/C JFHR2 fuse manufacturer & type
SP1401	600	6	Ferraz 6,9xx CP GRC
SP1402	600	6	Ferraz 6,9xx CP GRC
SP1403	600	6	Ferraz 6,9xx CP GRC
SP1404	600	8	Ferraz 6,9xx CP GRC
SP1405	600	10	Ferraz 6,9xx CP GRC
SP1406	600	16	Ferraz 6,9xx CP GRC

xx may be 00 (fuse with no trip indicator fitted) or 21 (fuse fitted with trip indicator).

Model	Volts DC	Amps DC	R/C fuse-type
SP2401	600	20	Ferraz 6,9xx CP GRC
SP2402	600	32	Ferraz 6,9xx CP GRC
SP2403	600	40	Ferraz 6,9xx CP GRC

Model	Volts DC	Amps DC	R/C fuse-type
SP3401	600	50	Ferraz 6,9xx CP GRC
SP3402	600	50	Ferraz 6,9xx CP GRC
SP3403	600	63	Ferraz 6,9xx CP GRC

DC fuses for Unidrive SP size 4 and higher should be sized at twice drive rated current and of a suitable DC voltage rating for the specific application.

If a system has a regen front end the DC fuses should be rated for at least 700Vdc.