

15P0161B1 - DCREG for Applications to Electromagnets - SW Rev. D4.01 R.05 - Updated 25/01/05

DRIVE POWER CONNECTIONS AND PROTECTING DEVICES

DCREG4 thyristor converter can be used to power very inductive loads, such as electromagnets. Applications problems due to this type of load - that can be compared to a ohmic resistance series-connected to a very strong inductance - have been solved by a control algorithm specially developed for DCREG4 converters.

With very inductive loads, safety problems may occur in case of power failure due to faults in the system or to unsafe installations. Power failure, in conjunction with the high inductive value of the magnet, can cause instant over voltage up to some thousands of Volts. The only way to protect the converter from those over voltage conditions consists in taking special measures when installing the equipment (see sections below).

Over voltage depends on how quick magnet power failure is:

$$V = L \frac{di}{dt}$$

Because L value is very high (approx. 1 Henry), the voltage value can reach instant values up to some thousands of Volts.

To protect the converter, the most effective measure consists in installing clamping unit **CU400**, which protects a DC converter when it is subject to dangerous over voltage conditions generated when the current conduction mesh of the magnet unexpectedly opens.

Energy stored in the magnet is obtained as follows:

$$E = \frac{1}{2} L I^2$$

Energy in the magnet is absorbed and stored in an RC-type clamping circuit, where over voltage is limited by a capacitor and energy is dissipated by a resistance, which are both integrated in the clamping circuit.

Clamping unit CU400 must be connected directly to the converter output by means of fuses equipped with a micro switch detecting power failure.

To ensure proper clamping, unit CU400 must be connected directly to the converter DC side. To suppress the first current peak generated by the capacitor, this is precharged when connecting the main voltage of the mains (typically 400 VAC) to the relevant terminals.

(Wiring diagram and terminal board are shown in Figure 1).

If the current conduction mesh on mains side opens (due to sliding contacts or other), or wires connecting the magnet to the converter are torn, the electric arc generated when current is cut off is limited by the clamping circuit, ensuring that over voltage does not exceed safety values.

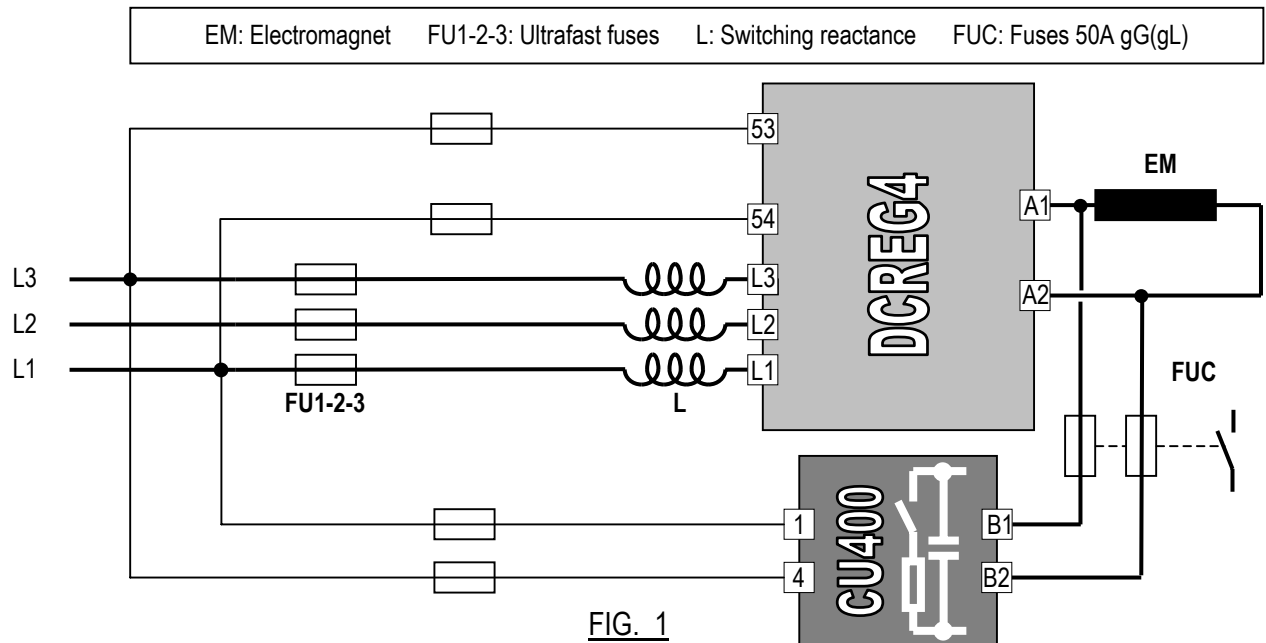
This setting is essential for electromagnets installed on bridge cranes where 3-phase supply voltage L1-2-3 is derived from the mains through sliding brushes that could accidentally open.

Multiple clamping units CU400 can be parallel-connected to the output of a unique converter. Each clamping unit is indicated for a rated DC current of approx. 150A as a maximum allowable value.

For more details, see CU400's Instruction Manual.

15P0161B1 - DCREG for Applications to Electromagnets - SW Rev. D4.01

R.05 - Updated 25/01/05

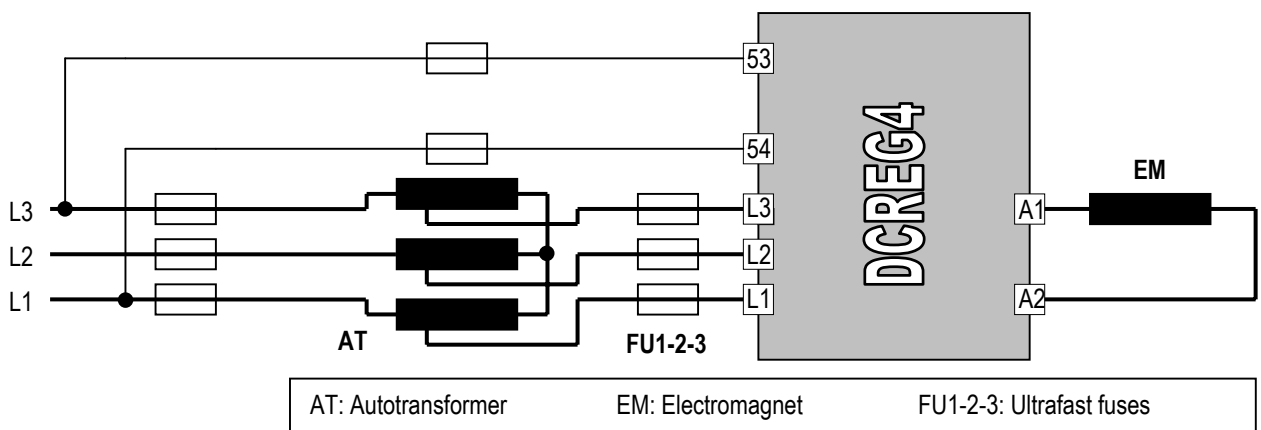


Otherwise, if you suppose that over voltage occurs only when the conduction mesh opens on mains side (3-phase supply voltage L1-2-3 derived from sliding brushes), another protective measure exists.

On mains side, install an **autotransformer** (see Fig. 2) which ensures current flowing even if one or more mains phases open.

To ensure the *boost* function (see below), voltage in the autotransformer secondary circuit should equal 1.5 ... 2 times the rated voltage of the electromagnet.

Apparent power of the autotransformer should be at least 50% stronger than DC power on electromagnet side. If a real autotransformer is used (not an isolating transformer), voltage in the secondary circuit should be at least 10 ... 20% weaker than voltage in the primary circuit, so as to avoid installing any switching inductance.



15P0161B1 - DCREG for Applications to Electromagnets - SW Rev. D4.01

R.05 - Updated 25/01/05

Finally, a third protective measure consists in using only a switching reactance on mains side (switching reactance is shown in Fig. 3).

This is the cheapest solution, but no protection is ensured, because no closing link of the magnet current is provided in case of power failure or output wire failure.

In that case, SCR modules are damaged by the over voltage caused by the magnet.

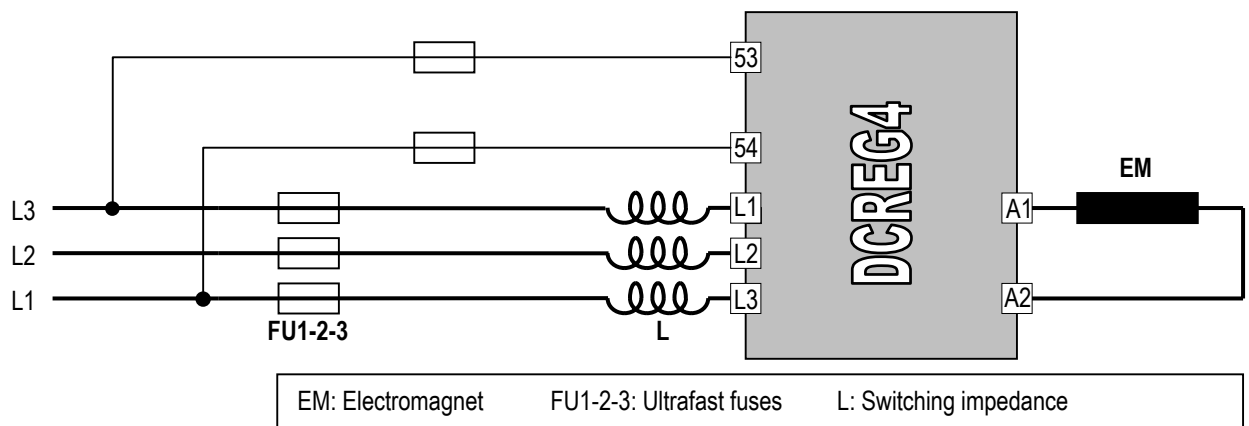


FIG. 3

15P0161B1 - DCREG for Applications to Electromagnets - SW Rev. D4.01

R.05 - Updated 25/01/05

DCREG4 ELECTROMECHANICAL DIAGRAM FOR REFERENCE SWITCHING

The diagram in Figure 4 illustrates how commands and references are managed both for magnetization/demagnetisation and for counter-energizing, which is essential to suppress residual magnetization.

If relays are used instead of a PLC, relays controlled by DCREG4's digital outputs may be equipped with AC or DC coils, provided that the maximum allowable power value is not exceeded. Because of weak current values (milliAmperes), use low capacity relays to make sure that contacts properly close.

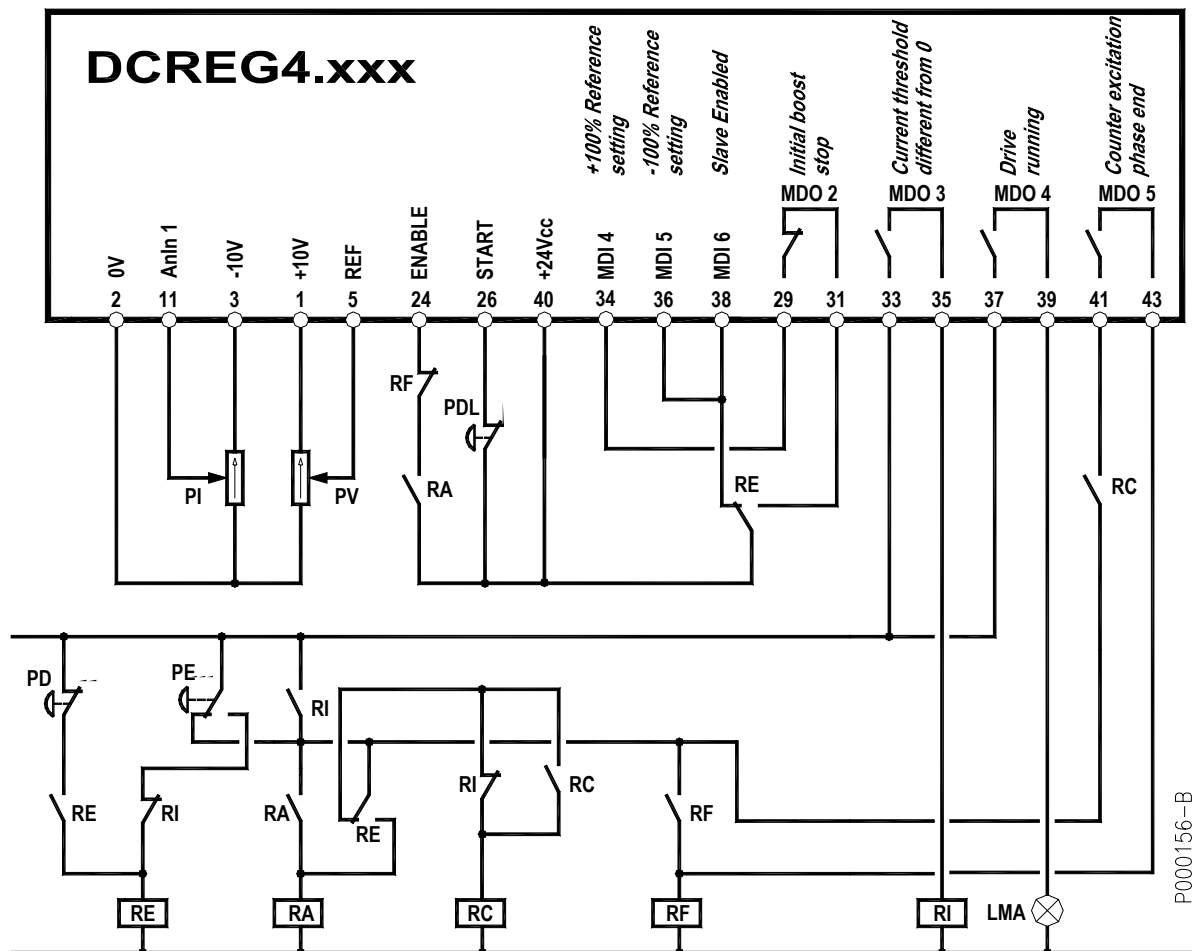


FIG. 4

LEGEND

| | |
|---|--|
| LMA: Indicator light, magnet on | RA: Relay, converter enabling |
| PD: Button, magnet deenergizing | RC: Relay, storage of counter-energizing beginning |
| PDL: Button, magnet partial deenergizing | RE: Relay, storage of energizing/deenergizing commands |
| PE: Button, magnet energizing | RF: Relay, end of cycle storage |
| PI: Potentiometer, counter-energizing current | RI: Relay, current in the magnet "on" |
| PV: Potentiometer, energizing voltage | |

15P0161B1 - DCREG for Applications to Electromagnets - SW Rev. D4.01 R.05 - Updated 25/01/05

DCREG4 SETTING PARAMETER VALUES DIFFERENT FROM DEFAULT VALUES

| | |
|---|---|
| P003 = 1 | <i>Advanced programming level</i> |
| P011 = 1.15 x V_{MAINSnom} | Boost DC voltage forcing energizing current |
| P031 = 10 s | <i>Down ramp time of positive voltage reference</i> |
| P034 = 60 s (example) | Down ramp during partial demagnetisation |
| P059 = 0.01 %/ μs | <i>Ramp over current reference</i> |
| P070 = 1 | <i>Proportional gain k_p of voltage regulator</i> |
| P071 = 0.1 s | <i>Integral time T_i of voltage regulator</i> |
| P100 = 1.5 | <i>Proportional gain k_p of current regulator</i> |
| P101 = 10 ms | <i>Integral time T_i of current regulator (discontinuous operation)</i> |
| P102 = 100 ms | <i>Integral time T_i of current regulator (continuous operation)</i> |
| $P122 = \frac{V_{\text{nom}}}{P011} \cdot 100$ | Gain over REF for magnet rated voltage as a percentage of boost voltage |
| P128 = 20% (example) | Gain over AnIn 1 for counter-energizing inverse current |
| P176 = 5 | <i>Digital output MDO 2 set as Drive Running</i> |
| P177 = 3 s (example) | <i>Digital output MDO 2 enabling delay for starting boost duration setting</i> |
| P181 = 1 | <i>Digital output MDO 2 set up with normally closed logic</i> |
| P185 = 5% | <i>Current threshold for programmable digital output MDO 3 as a perc. of I_{DRIVEnom}</i> |
| P195 = 3 s (example) | Time period of counter-energizing stage with inverse current |
| P211 = +100% | <i>PresetSpd 1 for boost upon energizing</i> |
| P212 = -100% | <i>PresetSpd 2 for boost upon deenergizing</i> |
| $C000 = \frac{I_{\text{nom}}}{I_{\text{DRIVEnom}}} \cdot 100$ | Magnet rated current expressed as a percentage of the converter size |
| C030 = V_{MAINSnom} | Three-phase, rated supply voltage for the converter |
| C070 = 4 | <i>Armature feedback</i> |
| C120 = 10 | <i>Auxiliary input AnIn 1 set as current limit for bridge B</i> |
| C134 = 2 | <i>Digital input MDI 5 ready for Preset Speed B setting</i> |
| C135 = 6 | <i>Digital input MDI 6 ready for Slave setting</i> |
| C150 = 1 | <i>Alarm A001 trip disabled (Field current failure)</i> |
| C151 = 1 | <i>Alarm A004 cleared (Load loss)</i> |
| C153 = 1 | <i>Alarm A006 trip disabled (Unstable mains frequency)</i> |
| C154 = 1 | <i>Alarm A007 trip disabled (No supply phase)</i> |
| C156 = 1 | <i>Alarm A010 trip disabled (Output over voltage)</i> |
| C157 = 1 | <i>Alarms A016/17 trip disabled (Tolerance exceeded by mains voltage)</i> |
| C170 = 1 | Selection of inductive load |

NOTES

1. Set **P000 = 1** to alter the parameters above.
2. **Save** all changes made to the parameters above. The remaining parameters are expected to be left at their default values (factory setting).
3. If an oscilloscope is used to monitor the response to a current reference step, temporarily change the value of parameter **C133** from 1: *Preset Speed A* (default value) to **6: Slave Enabled**. If so, the reference set on potentiometer PV (that must **not** be set at its max. value to avoid current limit) becomes a current reference, for the time set in P177. The current waveform may be read on terminal 8 by setting par. **P150** to **9: ArmatureCurr**.

15P0161B1 - DCREG for Applications to Electromagnets - SW Rev. D4.01 R.05 - Updated 25/01/05

DCREG4 OPERATION DESCRIPTION

If button **PE** is pressed, relay **RE** energizes, self-maintaining.

When **PE** returns to its initial position, relay **RA** energizes as well, self-maintaining.

Its contact on terminal 24 for *ENABLE* closes and the converter starts delivering output voltage. Indicator light **LMA** comes on to indicate that the magnet is on.

Closed contact of digital output *MDO 2* keeps digital input *MDI 4* active on terminal 34 for the time set in P177; DC output voltage is set (with par. P011 and P211), which is equal to mains 3-phase voltage increased by 15% (e.g. 460V_{DC} with 400V_{AC}).

Max. positive voltage which may be delivered by the converter with the default value of par. P230 (*AlfaMin*) is equal to $V = V_{SUPPLY} \cdot 1.36 \cdot \cos \alpha_{Min}$ (approx. +470V_{DC} with 400V_{AC}).

Then, the *boost* function activates, which considerably reduces the current rise time.

Current will reach the magnet rated value set in C000 within a given time. Even though the max. voltage reference is kept set for a longer time (par. P177), voltage delivered to the magnet terminal will drop anyhow (converter in current limit).

As soon as current is other than zero, *MDO 3* contact closes, thus energizing relay **RI**.

If energizing button **PE** is pressed at any moment, the duty cycle of the equipment is not affected, thanks to contact NO of **RI** parallel-connected to contact NC of button **PE** and to contact NC of **RI**, which is series-connected to contact NO of button **PE**.

When the time set in par. P177 is over, contact *MDO 2* opens, and the reference becomes the magnet rated voltage set in potentiometer **PV**, whose full-scale value is set in par. P122.

Switching from the max. voltage reference to the rated reference of the magnet, current drops, due to a larger resistance of the electromagnet winding when this heats up. Otherwise, if *boost* is set for a too long time (par.177), once the current rated value is reached, it is kept constant.

If button **PDL** is kept depressed for a given time, the voltage reference slowly drops following the ramp set in parameter P034 and unloading the material in excess (*partial demagnetisation*).

If button **PDL** is longer kept pressed, the converter shuts off and output voltage drops to zero; to set again the desired voltage, just release button **PDL**.

Even if the voltage reference returns to its initial value without following any preset ramp, current will rise slowly because the *boost* function is inactive.

If energizing button **PD** is pressed, relay **RE** deenergizes, and digital inputs *MDI 5* (terminal 36) and *MDI 6* (terminal 3) are activated: input voltage reference for terminal 5 is then switched to an internal current reference equal to the max. negative value.

This occurs with the maximum negative voltage that the converter can deliver; with the default value of par. P231 (*AlfaMax*) this is equal to $V = V_{SUPPLY} \cdot 1.36 \cdot \cos \alpha_{Max}$ (approx. -470V_{DC} with 400V_{AC}). The *boost* function enables, which considerably reduces current fall time.

15P0161B1 - DCREG for Applications to Electromagnets - SW Rev. D4.01 R.05 - Updated 25/01/05

As soon as current drops to zero, relay **RC** energizes, self-maintaining. Then, once current conduction switches from bridge A to bridge B, current becomes negative.

Bridge B is set to current limit due to the low value set through potentiometer **PI** and sent to auxiliary input *AnIn 1*, which is configured as current limit for bridge B through parameter C120. Its incoming signal is weakened by parameter P128 to exploit the whole scale of the potentiometer.

Current is kept constant for the time set in parameter P195 (residual magnetization is suppressed); when the time set in P195 is over, contact of digital output *MDO 5* closes (*MDO 5* is set as “current limit attained” by default) and relay **RF** is energized, self-maintaining.

Contact NC of **RF** on terminal 24 of *ENABLE* opens (stand-by command), so current is forced to zero with the max. positive voltage available applied to the magnet (approx. +470V_{DC} with 400V_{AC}).

When voltage and current cancel out, the converter is really disabled; contact *MDO 4* opens and turns off indicator light **LMA**.

As soon as current drops below the current threshold, relay **RI** deenergizes, thus allowing to send a new energizing command.

When button **PE** is pressed again, self-maintenance is disabled for relays **RA**, **RC**, **RF**, and the operating cycle can start again.

NOTE: What explained in the section above concerns loads consisting in only one electromagnet (or in a fixed number of electromagnets) and loads consisting in a variable number of electromagnets, e.g. multiple parallel-connected electromagnets, some of which can be disabled.

If a variable number of electromagnets is used, you must adjust the value of the counter-energizing inverse current set in potentiometer **PI** each time the converter is used, in order to make sure that the current value for each electromagnet always corresponds to the desired value.

15P0161B1 - DCREG for Applications to Electromagnets - SW Rev. D4.01

R.05 - Updated 25/01/05

DCREG2 ELECTROMECHANICAL DIAGRAM FOR REFERENCE SWITCHING

The diagram in Figure 4a illustrates how commands and references are managed both for magnetization and for demagnetisation. Using a DCREG2, the phase of counter-energizing, which is essential to suppress residual magnetization, is no more available.

If relays are used instead of a PLC, relays controlled by DCREG2's digital outputs may be equipped with AC or DC coils, provided that the maximum allowable power value is not exceeded. Because of weak current values (milliAmperes), use low capacity relays to make sure that contacts properly close.

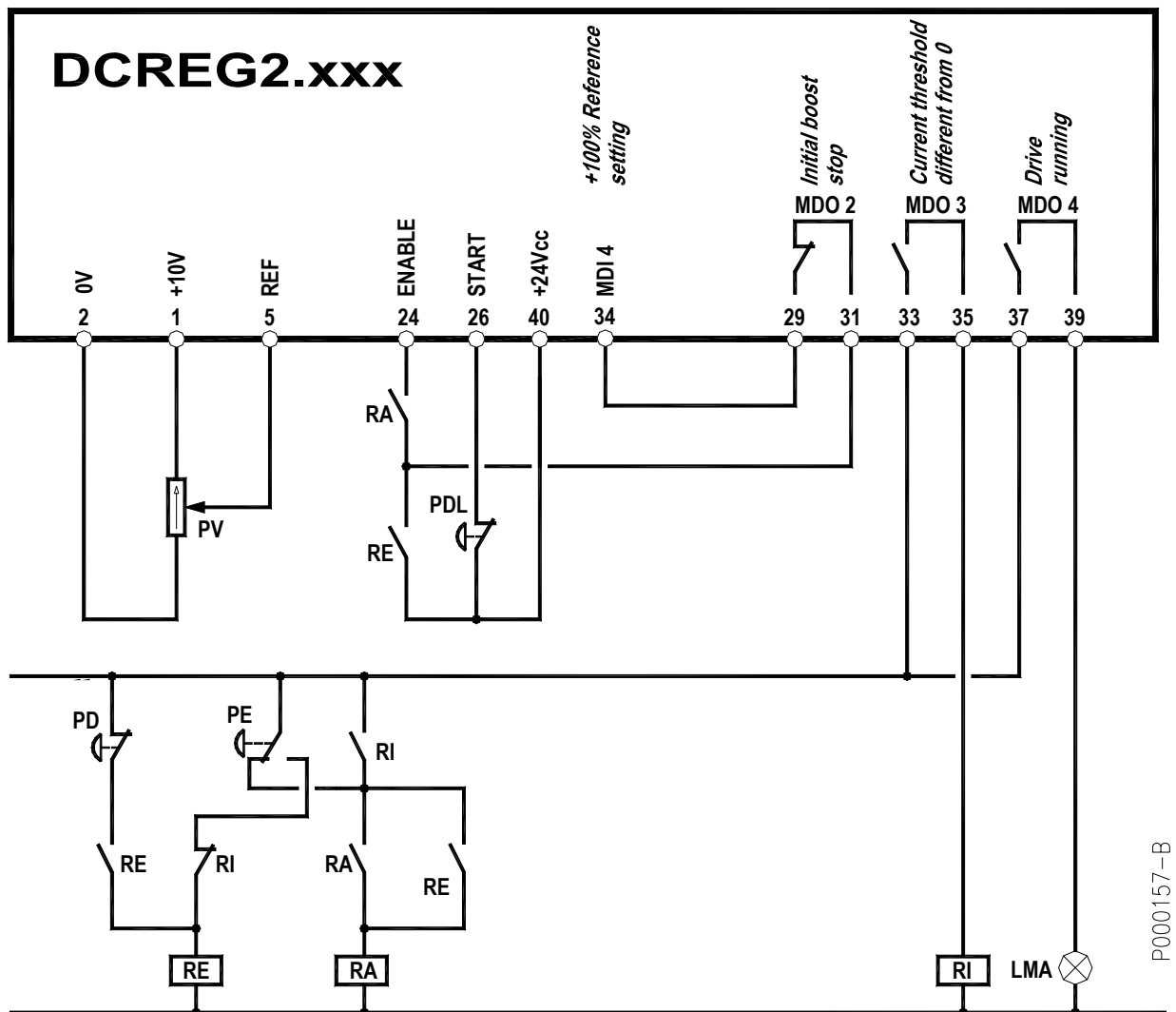


FIG. 4a

LEGEND

- | | |
|--|--|
| LMA: Indicator light, magnet on | PV: Potentiometer, energizing voltage |
| PD: Button, magnet deenergizing | RA: Relay, converter enabling |
| PDL: Button, magnet partial deenergizing | RE: Relay, storage of energizing/deenergizing commands |
| PE: Button, magnet energizing | RI: Relay, current in the magnet "on" |

15P0161B1 - DCREG for Applications to Electromagnets - SW Rev. D4.01 R.05 - Updated 25/01/05

DCREG2 SETTING PARAMETER VALUES DIFFERENT FROM DEFAULT VALUES

| | |
|---|--|
| P003 = 1 | <i>Advanced programming level</i> |
| P011 = 1.15 x $V_{MAINSnom}$ | Boost DC voltage forcing energizing current |
| P031 = 10 s | <i>Down ramp time of positive voltage reference</i> |
| P034 = 60 s (example) | Down ramp during partial demagnetisation |
| P059 = 0.01 %/ μ s | <i>Ramp over current reference</i> |
| P070 = 1 | <i>Proportional gain k_p of voltage regulator</i> |
| P071 = 0.1 s | <i>Integral time T_i of voltage regulator</i> |
| P100 = 1.5 | <i>Proportional gain k_p of current regulator</i> |
| P101 = 10 ms | <i>Integral time T_i of current regulator (discontinuous operation)</i> |
| P102 = 100 ms | <i>Integral time T_i of current regulator (continuous operation)</i> |
| P122 = $\frac{V_{nom}}{P011} \cdot 100$ | Gain over REF for magnet rated voltage as a percentage of boost voltage |
| P176 = 5 | <i>Digital output MDO 2 set as Drive Running</i> |
| P177 = 3 s (example) | <i>Digital output MDO 2 enabling delay for starting boost duration setting</i> |
| P181 = 1 | <i>Digital output MDO 2 set up with normally closed logic</i> |
| P185 = 5% | <i>Current threshold for programmable digital output MDO 3 as a perc. of $I_{DRIVEnom}$</i> |
| P211 = +100% | <i>PresetSpd 1 for boost upon energizing</i> |
| P230 = 30° | <i>Minimum delay angle</i> |
| C000 = $\frac{I_{nom}}{I_{DRIVEnom}} \cdot 100$ | Magnet rated current expressed as a percentage of the converter size |
| C030 = $V_{MAINSnom}$ | Three-phase, rated supply voltage for the converter |
| C070 = 4 | <i>Armature feedback</i> |
| C150 = 1 | <i>Alarm A001 trip disabled (Field current failure)</i> |
| C151 = 1 | <i>Alarm A004 cleared (Load loss)</i> |
| C153 = 1 | <i>Alarm A006 trip disabled (Unstable mains frequency)</i> |
| C154 = 1 | <i>Alarm A007 trip disabled (No supply phase)</i> |
| C156 = 1 | <i>Alarm A010 trip disabled (Output over voltage)</i> |
| C157 = 1 | <i>Alarms A016/17 trip disabled (Tolerance exceeded by mains voltage)</i> |
| C170 = 1 | Selection of inductive load |

NOTES

1. Set **P000 = 1** to alter the parameters above.
2. **Save** all changes made to the parameters above. The remaining parameters are expected to be left at their default values (factory setting).
3. If an oscilloscope is used to monitor the response to a current reference step, temporarily change the value of parameter **C133** from 1: *Preset Speed A* (default value) to **6: Slave Enabled**. If so, the reference set on potentiometer PV (that must **not** be set at its max. value to avoid current limit) becomes a current reference, for the time set in P177. The current waveform may be read on terminal 8 by setting par. **P150** to **9: ArmatureCurr**

15P0161B1 - DCREG for Applications to Electromagnets - SW Rev. D4.01

R.05 - Updated 25/01/05

DCREG2 OPERATION DESCRIPTION

If button **PE** is pressed, relay **RE** energizes, self-maintaining.

When **PE** returns to its initial position, relay **RA** energizes as well, self-maintaining.

As a consequence, the series of two contacts on terminal 24 for **ENABLE** closes and the converter starts delivering output voltage. Indicator light **LMA** comes on to indicate that the magnet is on.

Closed contact of digital output **MDO 2** keeps digital input **MDI 4** active on terminal 34 for the time set in P177; DC output voltage is set (with par. P011 and P211), which is equal to mains 3-phase voltage increased by 15% (e.g. 460V_{DC} with 400V_{AC}).

Max. positive voltage which may be delivered by the converter with the value of 30° in par. P230 (*AlfaMin*) is equal to $V = V_{SUPPLY} \cdot 1.36 \cdot \cos \alpha_{Min}$ (approx. +470V_{DC} with 400V_{AC}).

Then, the *boost* function activates, which considerably reduces the current rise time.

Current will reach the magnet rated value set in C000 within a given time. Even though the max. voltage reference is kept set for a longer time (par. P177), voltage delivered to the magnet terminal will drop anyhow (converter in current limit).

As soon as current is other than zero, **MDO 3** contact closes, thus energizing relay **RI**.

If energizing button **PE** is pressed at any moment, the duty cycle of the equipment is not affected, thanks to contact NO of **RI** parallel-connected to contact NC of button **PE** and to contact NC of **RI**, which is series-connected to contact NO of button **PE**.

When the time set in par. P177 is over, contact **MDO 2** opens, and the reference becomes the magnet rated voltage set in potentiometer **PV**, whose full-scale value is set in par. P122.

Switching from the max. voltage reference to the rated reference of the magnet, current drops, due to a larger resistance of the electromagnet winding when this heats up. Otherwise, if *boost* is set for a too long time (par.177), once the current rated value is reached, it is kept constant.

If button **PDL** is kept depressed for a given time, the voltage reference slowly drops following the ramp set in parameter P034 and unloading the material in excess (*partial demagnetisation*).

If button **PDL** is longer kept pressed, the converter shuts off and output voltage drops to zero; to set again the desired voltage, just release button **PDL**.

Even if the voltage reference returns to its initial value without following any preset ramp, current will rise slowly because the *boost* function is inactive.

If energizing button **PD** is pressed, relay **RE** deenergizes: this will cause opening the series of two contacts on terminal 24 for **ENABLE**, setting stand-by command. As a consequence, input voltage reference for terminal 5 is then switched to a current reference equal to zero.

Fall down to this value is performed with the maximum negative voltage that the converter can deliver; with the default value of par. P231 (*AlfaMax*) this is equal to $V = V_{SUPPLY} \cdot 1.36 \cdot \cos \alpha_{Max}$ (approx. -470V_{DC} with 400V_{AC}). The *boost* function enables, which considerably reduces current fall time.

When voltage and current cancel out, the converter is really disabled; contact **MDO 4** opens and turns off indicator light **LMA**.

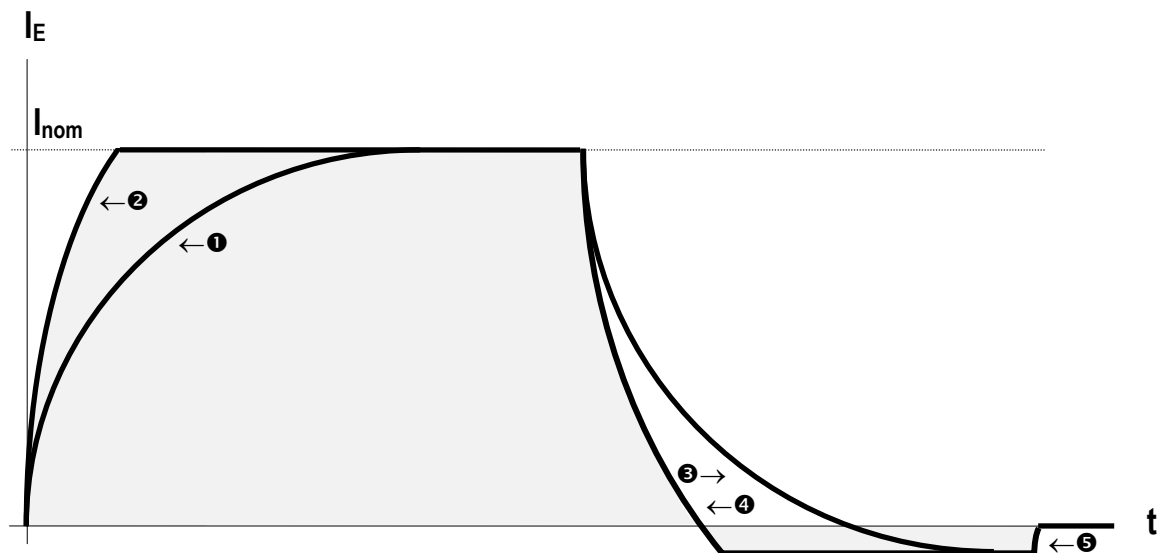
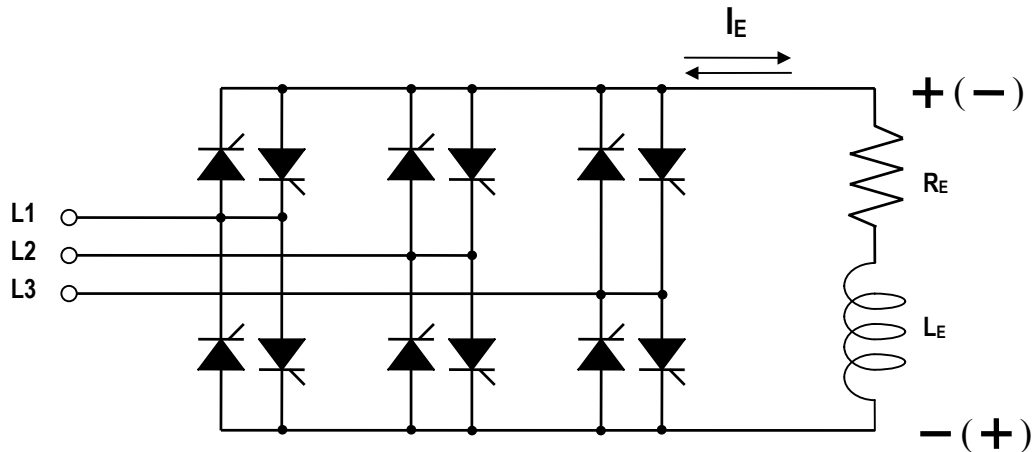
As soon as current drops below the current threshold, relay **RI** deenergizes, thus allowing to send a new energizing command.

When button **PE** is pressed again, self-maintenance is disabled for relay **RA**, and the operating cycle can start again.

15P0161B1 - DCREG for Applications to Electromagnets - SW Rev. D4.01

R.05 - Updated 25/01/05

ENERGIZING/DEENERGIZING CURRENT PATTERNS



Electromagnet energizing:

- ❶ Rated voltage positive reference
- ❷ Rated current positive reference, i.e. max. voltage positive reference (a)

Electromagnet deenergizing and suppression of residual magnetization:

- ❸ Voltage negative reference
- ❹ Current negative reference, i.e. max. voltage negative reference (b)
- ❺ Zero current reference (Run contact open) (a)

(a) Positive voltage limited to firing angle " α_{motor} "

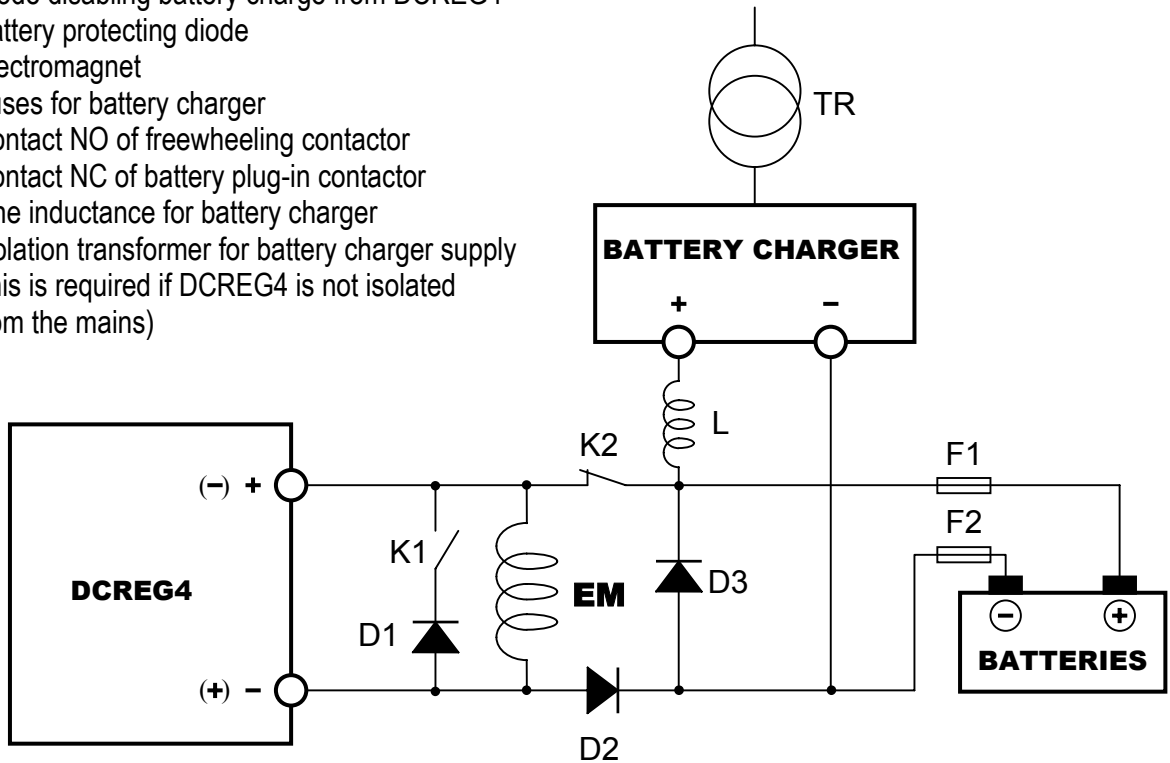
(b) Negative voltage limited to firing angle " α_{brake} "

15P0161B1 - DCREG for Applications to Electromagnets - SW Rev. D4.01

R.05 - Updated 25/01/05

OPERATION WITH SAFE BATTERIES

- D1: Freewheeling diode for electromagnet
- D2: Diode disabling battery charge from DCREG4
- D3: Battery protecting diode
- EM: Electromagnet
- F1-2: Fuses for battery charger
- K1: Contact NO of freewheeling contactor
- K2: Contact NC of battery plug-in contactor
- L: Line inductance for battery charger
- TR: Isolation transformer for battery charger supply
(this is required if DCREG4 is not isolated from the mains)



OPERATION SEQUENCE

For safety reasons, coil in contactor K2 voltage is derived from the mains, with normally closed power poles. When supply mains is on, poles are open.

When voltage is removed, poles of contactors K1 and K2 must instantly close. Battery supply is then delivered to the electromagnet.

When the converter comes on again, external contacts and the DCREG4 reference must be capable of starting it up immediately (electromagnet energizing with a properly large voltage reference). If no alarm trips, an external **timer** must be enabled. When its counting is over and the DCREG4 is adjusting a voltage value higher than the voltage supplied to the batteries (see section below), freewheeling diode and reserve batteries may be disconnected. Poles of contactors K1 and K2 open again.

If voltage is removed while deenergizing (i.e. after pressing button PD), batteries shall **not** activate, because if counter-energizing has already started, DCREG4 output should be short-circuited from diode D1.

NOTE 1. Diodes D1...3 are to be dimensioned for a current value equal to the electromagnet current and for inverse voltage equal to 1600V, provided that DCREG4 3-phase supply does not exceed 440V.

NOTE 2. Current used to charge safe batteries can be equal to 10% of their capacity in Ah, for a time period of approx. 10h.

15P0161B1 - DCREG for Applications to Electromagnets - SW Rev. D4.01

R.05 - Updated 25/01/05

ALARMS

If a failure is detected, an alarm trips and stops the converter. Default setting of digital output *MDO 1* is *0:Drive OK*.

Two conditions may occur:

- 1) After 0.5 s, the alarm tripped is stored to E²PROM.
- 2) The alarm tripped is NOT stored to E²PROM (e.g. failure of one or more supply phases).

If the alarm tripped is stored to E²PROM and the cause responsible for the alarm has disappeared, send a **reset** command to terminal **28** (*MDI 1*), which is factory-set to *0:Reset*.

If the alarm is not stored to E²PROM (failure of one or more supply phases), when mains supply comes on again and if the *ENABLE* contact is still closed, the converter is self-reset, but will be able to restart only after 10s from the instant when power is restored. This is a safety delay set in par. C101 (*PwrOn Time*) (factory-setting: 10s).

The safety delay is enabled only for the first start-up after a power failure.

If safe batteries are installed, which activate in case of power failure, the time set in the external timer must be longer than 10s.

Safe battery voltage can be higher (at least in a first stage) than the magnet rated voltage; also, voltage set in the potentiometer can be accidentally too low. Make sure that the voltage regulated by the converter is **higher** than the battery voltage when batteries are on and the converter is operating again; if not, the converter will tend to discharge safe batteries. To do so, contact between terminals 29 and 31 (*MDO 2*) must be kept closed for the required time period.