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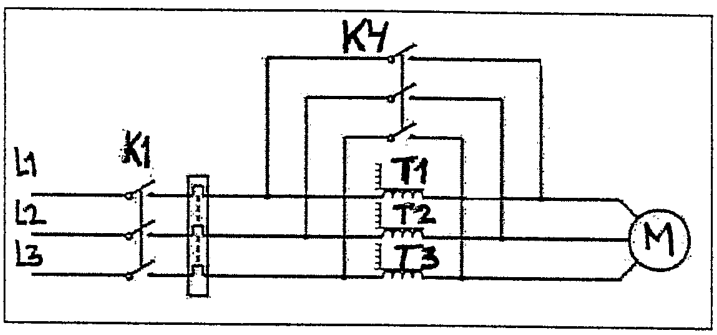
(54) **Title:** SOFT STARTER FOR ASYNCHRONOUS MOTOR




**(57) Abstract:** The invention is related to a soft start device for an asynchronous motor by means of a current limiting element situated between the motor and a power line, a start line with at least one current limiting element, a bypass line with bypass contactor for connecting the motor directly to the power line, and a control unit for controlling the impedance of the current limiting element and the bypass contactor. A variable reactor in the start line comprises a main winding and a control winding, where the main winding constitutes the current limiting element in the start line, and the control winding together with means for regulating the current flowing in the control winding constitute means for controlling the reactance of the current limiting element and thus the current provided to the motor. The invention is also related to soft start and soft stop methods.

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**Soft Starter for Asynchronous Motor**

The present invention concerns a soft start device for an asynchronous motor comprising at least one current limiting element to be arranged in a start line between the motor and a power line, a bypass line with a bypass contactor for connecting the motor directly to the power line and a control unit for controlling the current limiting element and the bypass contactor.

The starting current of an AC motor can vary from 3 times the nominal current to 7 times the nominal current. This is because a large amount of energy is required to magnetize the motor sufficiently to overcome the inertia the system has at standstill. The high current drawn from the network can cause problems such as voltage drops, high current transients and in some cases uncontrolled shutdown.

A high start current also causes high mechanical stress in the motor's rotor bars and windings, and can affect the driven equipment and the foundations.

Several starting methods exist, all aiming to reduce said stresses. The type and magnitude of the load, the motor and the supply network determine the most appropriate start method. Start methods which do not lead to high current peaks, are called "soft starts".

When selecting and dimensioning the starting equipment and any protective devices, the following factors are normally taken into consideration: a) Voltage drop in the supply network when starting the motor, b) required load torque during start, c) required start time.

As stated above, there are several known methods and circuits for connecting a motor to a power supply. These include:

1) Direct on line

The corresponding circuit is shown in figure 1. The circuit comprises an electro mechanical switch that is closed and opened to respectively start and stop the motor. The main disadvantages of this system are that it leads to a high inrush current (typically 6 times the system's full load current), which can among other things cause a reduction in the service life of the electrical components. The installation must be oversized to be able to put up with this high transition current, this being particularly important for the generator and UPS fed supplies. Besides, the high current limits the expansion of the system. Regarding the mechanical aspects, this start method and circuit lead to an excessive starting torque for the motor (typically 2.5 times the full load torque), an increase in the drive chain components wear, and it reduces the mechanical components' service life.

2) Star/delta

The corresponding circuit is shown in figure 2. This method requires that both connections for each phase (six in all) be taken to the starter. Three contactors are used to first connect the motor in star configuration and after a given time in delta configuration. Connecting the motor in star reduces the voltage applied to each winding to about 60% of the line voltage. This reduces the starting torque and current (typically 3.5 x FLC, full load current). After a given time the motor is switched to delta connection and then runs as if direct on line. The main advantages of this method are that it is relatively simple and has low costs. The major problem is that there are only two voltage levels available, and that the transition from one level to the other follows a step function. Sometimes the lower voltage is not ideal, because the torque produced (65% of full load torque) may be too small in relation to the necessary torque for moving the load, and the motor stalls or does not give complete acceleration. If the lower voltage is too high the motor still starts with a pronounced jerk. The star/delta transition will produce a transition peak of up to 20 times the nominal current, that is a second current and torque peak that is almost the equivalent of having two direct-on-line starts. On some loads the motor will almost stall during this transition time. This method has thus a clearly limited range of application.

3) Stator starter using resistors

This circuit is shown in figure 3. Resistors connected in series with the motor windings are used as ballast for soft starting. The resistors reduce the voltage in the starting moment, and are bypassed after the start up sequence. This is a simple method for regulating the start voltage but has the same disadvantages as the star/ delta starter in 2) and in addition losses generated in the resistors.

4) Reactor Start

This circuit is shown in figure 4. By connecting a coil with an iron core (a reactor) in series with the motor during start, the starting current is limited in proportion with the voltage. However, this also means a substantial (quadratic) reduction in the available starting torque. The advantage of this method is its low cost in comparison with other methods.

5) Autotransformer starter

This circuit is shown in figure 5. This method uses transformer action to reduce the voltage applied to the motor and current seen by the supply. An improved torque/amp ratio is achieved and starting current is typically 3 times FLC (full load current), depending on the voltage tapping selected. Normally the voltage is applied to the motor in voltage steps through the transformer with the taps being selected through contactors. Typical tappings are 50%, 70%, followed by full voltage being applied to the motor. The major disadvantages are the large size of the autotransformer and its high costs, and of course the mechanical jerk at switch on is not controllable and can still cause problems. Also once the tappings have been selected, it may be necessary to change them according to changes in load parameters, that is, it is difficult to adapt the system to various working conditions.

6) Electronic soft start

The corresponding circuit is shown in figure 6. This circuit is designed to apply an adjustable voltage to the motor and increase this voltage gradually over a user-selectable acceleration period, the acceleration time being dependent on the application and desired characteristics. The added advantage of this method of reduced voltage control is that the motor can also be stopped gradually by slowly reducing the output voltage. This 'Soft Stop' feature offers a smooth stop in many process industries such as pumps, where fast stops can result in 'water hammer' and mechanical damage. However this circuit produces harmonic currents which may disrupt other processes, has a low resilience, and its functional dependence on electronic devices leads to low reliability.

In view of the above-mentioned disadvantages related to the prior art, the invention is aimed at providing a new soft start device for starting an asynchronous motor that permits a swift variation of the start torque and the start current without need for semiconductor devices in the power circuit.

The invention comprises a soft start device for an asynchronous motor, comprising:
- at least one current limiting element to be arranged in a start line between the motor and a power line and arranged to control the current delivered to the motor,

- a bypass line with a bypass contactor for connecting the motor directly to the power line,

- a control unit for controlling the current limiting element and the bypass contactor.

The device according to the invention is characterized in that it comprises at least one variable reactor with a main winding and a control winding, where the main winding constitutes the current limiting element in the start line, and the control winding together with means for regulating the current flowing in said control winding constitute means for controlling the reactance of the current limiting elements.

In a preferred embodiment of the invention, the main winding and the control winding are wound around a ferromagnetic core so that the magnetic field created by the main winding is orthogonal to the magnetic field created by the control winding. An example of such a device is described in the applicants' international application PCT/NO01/00217.

The variable reactors are used as ballasts during the start period. These reduce the voltage in the starting moment, and are bypassed after the start up sequence.

In one embodiment of the invention, the control winding's current regulating means are adapted to increase the current in the control winding from a start magnitude to a final magnitude. The final magnitude can be a predetermined magnitude or it can depend on other parameters, as for example the magnitude attained by the current when a predetermined time period has elapsed (this time control being performed by a timer unit).

The control unit comprises in one embodiment of the invention a device for measuring current in the main winding and controlling the operation of the variable reactor based on this magnitude. The bypass of the reactors when the start period is over is determined by settings and current magnitude or, as mentioned above by a timer unit.

In a preferred embodiment of the invention the control winding's current regulating means are implemented as half controlled, single-phase rectifiers with free wheeling diode as power source for the current.

The variable reactors are in a preferred embodiment of the invention linear electrical adjustable reactors, and they comprise a core, a main winding and a control winding, the axis of the main winding being perpendicular to the axis of the control winding.

According to the invention the current limiting element for controlling the current supplied to the motor is implemented as the main winding in a variable reactor with a main winding and a control winding, and the reactance of the current limiting element is controlled by regulating the current flowing in the control winding.

Said regulation of the current flowing in the control winding is done by increasing the current from a start magnitude to a final magnitude by means of a connecting circuit as described above.

In a preferred embodiment of the invention regulation of the current flowing in the control winding is done by means of a half-controlled, single-phase rectifier with a free wheeling diode.

The linear adjustable inductors can be designed for any given voltage and current. The main winding of the controllable reactor has a sufficiently high reactance for safe starting of the motor, and as part of the starting process this reactance is ramped down to a sufficiently low level for normal operation and eventual bypassing of the controllable reactor.

The invention has several important advantages compared with the prior art. It makes it possible to vary the start current and the start torque without production of harmonic currents, in a simple manner and without being dependent of semiconductor technology in the power circuit. This last feature leads to a highly reliable system since all components of the power circuit are robust. The mechanical stress is also reduced and the acceleration can be controlled more efficiently.

In the same way as the prior art electronic soft start circuit, the device and method according to the invention can be used for providing a reliable deceleration and stop of the motor. In this case a changeover is made from the bypass line to the start line with a maximum magnitude for the controlling current (minimum reactance), thereafter the reactance is gradually increased until a maximum is reached, thus reducing the magnitude of the motor current to a low level, and at this moment the power supply is disconnected from the motor.

The variable reactors in the device according to the invention are designed to have sufficiently low impedance at saturation to permit that the necessary torque for starting the motor is attained.

The invention also comprises a method for connecting an asynchronous motor to a power line by means of at least one current limiting element arranged between the motor and the power line, comprising:

- connecting the motor to the power line through a start comprising a variable reactor with a main winding and a control winding, where the variable reactor's main winding constitutes the current limiting element in the start line,

- gradually reducing the reactance of the main winding of the variable reactor by increasing the current flowing in at least one control winding of the variable reactor, and

- connecting the motor directly to the power line through a bypass line when one or more predefined conditions have been fulfilled.

The invention comprises also a method for disconnecting an synchronous motor from a power line by means of at least one current limiting element arranged between the motor and the power line comprising, in a state where the motor is connected to the power line through a line comprising a variable reactor with a main winding and a control winding, and the variable reactor's main winding constitutes the current limiting element:

- gradually increasing the reactance of the main winding of the variable reactor by decreasing the current flowing in the control winding of the variable reactor, and
- disconnecting the motor from the power line when one or more predefined conditions have been fulfilled.

The predefined conditions can be e.g. that a predetermined maximum or minimum current value is attained, or that a predetermined time period has elapsed, or a combination of these.

The methods comprise use of a variable reactor with a main winding and a control winding, where the main winding constitutes a current limiting element in the start line, and impedance control of the reactor is performed by regulating the current flowing in the control winding.

The invention will now be described in detail with reference to the drawings, which show a preferred embodiment of the invention. Although the invention will be described in relation with motor start, it will be clear for the skilled man that it is possiblw to invert the process and to use the invention for soft stop.

Figures 1-6 illustrate the prior art.

Figure 7 shows a general diagram of the circuit according to the invention.

Figure 8 shows a functional diagram of one embodiment of the invention.

Figure 9 shows the switch control logic in the above-mentioned embodiment of the invention.

Figure 10 and 11 show a connection diagram for one implementation of the functional diagram in figure 8.

Figure 11 shows the control unit with means for regulating the current in the control windings.

Figure 12 illustrates the in rush current with direct on line start.

Figure 13 illustrates the in rush current with the circuit according to the invention and no control current.

Figure 14 illustrates the in rush current with the circuit according to the invention with maximum control current.

Figure 15 illustrates the maximum control current.

Figures 1-6 illustrate the prior art and are already described in the introductory part of this specification.

Figure 7 shows a general diagram of the soft start device or soft starter according to the invention. This figure comprises power lines L1, L2, L3, external contactor K1 comprising three switches, one in each power line L1, L2, L3, and over current protection, bypass contactor K4 in a bypass line, and series connected variable reactors T1, T2, T3 in a start line. The control circuit for the variable reactors T1, T2, T3 is not shown in this figure.

Figure 8 shows a more detailed view of one embodiment of the invention by way of a functional diagram. The variable reactor and the bypass contactor K4 are connected to the power lines (here shown as only one line) over contactor K1. According to this embodiment contactor K1 also includes a fourth contact K1:43,44 between a control unit and an auxiliary power line. In other words, according to this embodiment the control unit is powered from a power source different from that of the variable reactor and the motor, but the operation of contactor K1 will simultaneously connect the variable reactor, the bypass contactor and the control units to their respective power sources.

The use of a separate power source for the control unit is, however, not a necessary condition, the main power line L1, L2, L3 could also be used to power the control unit.. Also, the inclusion of contacts K1:43,44 as part of the contactor K1 is not necessary. As any skilled person will understand, this switch may be separate form K1 and independently operated, as a matter of design choice.

Figure 9 shows the switch control logic of the embodiment of figure 8. The figure shows external contactor K1:43,44, which connects the control unit with the auxiliary power line. Following the external contactor is relay K5, main switch S1, the bypass relay K4 and timer TR5. When contactor K1 is operated, contact K1:43,44 energizes relay K5, which will be described in further detail below, and timer TR5. After a preset period of time timer TR5 closes switch TR5:15,16, which energizes relay K4, closing the switches of contactor K4 and bypassing the variable reactor. Main switch S1 allows manual bypass of the variable reactor.

It should be noted that the timer TR5 could be replaced with some other control circuit that would close the bypass contactor K4 as a result of other criteria than the elapse of a set time period, such as the measured current through the variable reactor reaching a predetermined level.

Figure 10 shows a connection diagram for one implementation of the functional diagram in figure 8. In this diagram the structure of the variable reactors T1, T2, T3 is shown. The reactors comprise a main winding in terminals T1-T3:1,2 which constitutes a current limiting element for the motor current, and control windings in terminals T1-T3:3,4 which control the reactance of the main windings. L1, L2, L3 denote the power line input, L, N denote the auxiliary line input, and U, V, W denote the motor connection.

Figure 11 shows additional details of the control unit, including a thyristor firing board U1, a thyristor bridge U3 with a freewheeling diode V5. The firing board U1 is enabled by an enabling line including contacts K5:3,4, K4:31,32 and S1:3,4. A variable resistor R5 sets the current's maximal level

When switch S1 is set in operation mode, S1:1,2 is opened to disable automatic bypass, and S1:3,4 in the enabling path is closed to make the control card ready for closure of contacts K5:3,4 of the enabling relay K5. K4:31,32 is closed at this time. The control unit is now in operating mode and waiting activation of contactor K1 to energize the control unit.

When K1 is activated the variable reactor and the bypass contactor are connected to the main power line L1, L2, L3, and the control unit is connected to auxiliary power line L, N. When this happens relay K5 is triggered, closing contact K5:3,4, which closes the enabling path of the firing board U1. Also, the timer TR5 is activated. In addition the thyristor bridge U3, which is powered from two of the three phases L1, L2 of the main power line, starts to conduct according to preset variable resistor R5.

The rectified voltage output from the thyristor bridge U3 supplies voltage to the control windings connected between contact points T1-T3:3,4 of the variable reactor T1, T2, T3, which in the example illustrated in figure 10 are connected in series.

When the voltage is applied to the control windings the current flowing through these windings cannot change instantaneously due to the inductance of the windings. Instead, the current will build up gradually until it reaches a level dependent on the preset level of the thyristor bridge as set by variable resistor R5. This level should be adjusted to a level that will result in saturation of the core by the field induced by the control windings.

As a result of the increased current through the control windings and the eventual saturation of the core, the permeability of the reactor core will change and consequently the reactance of the main windings, situated between contact points T1-T3:1,2 and constituting the current limiting elements of the variable reactor, will also change. This reactance will be lowered from an initial level and current through the main windings to the motor increases.

When the time set by timer TR5 elapses, switch TR5:15,16 closes and triggers relay K4. This closes bypass contactor K4 supplying power directly to the motor, and opens switch K4:31,32, disabling the firing board U1. Thyristor firing then ceases, and the control current through the control windings ramps down through the freewheeling diode V5.

When external contactor K1 again is opened, contactor K4 and relay K5 will no longer be energized, and they will return to their initial states, timer TR5 will be reset and the soft starter is ready for a new start process. Relay K5 has the additional function of preventing enabling the firing board in case of a power failure.

The embodiment of the invention shown in figures 8-10 was implemented for starting motors in a sawmill installation. In this case it was desired to halve the starting current. Measuring tests on the motor showed a peak value of 800A, which thus was to be lowered to 400A. By inserting a variable reactor element in each phase of the motor supply line the current limiting is obtained.

Figures 12-15 show diagrams of the start current, that is, the current that is supplied to the motor with different start techniques. The diagram is the result of experiments performed on a 10kW motor.

Figure 12 shows the inrush current with direct on-line start (the corresponding circuit is shown in figure 1). As one can see, this current has a high peak of 500A and the motor starts in 1.5s. (Time scale is seconds.)

Figure 13 shows the inrush current in a circuit according to the invention with no control current. The operation is the same as in 4) reactor start with a fixed reactor size. The reactor limits the motor current at startup until at about 5s the motor has full speed.

Figure 14 shows the inrush current in a circuit according to the invention with maximum control current. As one can see, the start time is considerably reduced compared with the situation with no control current and at the same time the peak value of the inrush current is reduced compared with the situation in the direct on line start.

Figure 15 shows the variation of the control current with time. This is increased linearly with time until a first value is reached, after this it is kept at a constant level, and it increases again when the motor has reached its steady state.

With a more sophisticated control e.g. using a plc or more logic if it is advantageous for the application the soft start also could be used as a soft stop reversing the start process. A soft stop is implemented by energizing the variable reactor control winding to a low level of reactance and switching the by pass contactor off. The reactance then takes over the load current and while reducing the control current, the reactance increases to a high level in a soft manner and the motor current is decreased at the same time. When the motor current has reached a sufficient low level then the main contactor K1 disconnects the power line. This will call for other logic than shown in fig 9, e.g. the external contactor is to be controlled by a signal from the soft starters control unit. In this case the control unit is adapted to control the impedance of the variable reactor to perform a soft stop and the control winding's current regulating means are adapted to decrease the current in the control winding from a start value to a final value.

The control winding's current regulating means can also be implemented as a H bridge IGBT device with free wheeling diode on each IGBT, the H bridge powered from a dc voltage. Said DC voltage can e.g. be a rectified voltage from the control voltage supply. The control winding will in this case be located between the two half bridges so that the current delivered to the control winding can be switched in both directions through the winding and the control unit is equipped with a current measurement device to monitor the current in the control winding current flowing in the control winding be monitored for optimum control of motor current. Monitoring will also be achieved to obtain precise control of the motor current according to the demand of torque on the motor axis.

Claims

1. Soft start device for an asynchronous motor, comprising

-at least one current limiting element to be arranged in a start line between the motor and a power line and arranged to control the current delivered to the motor,

-a bypass line with a bypass contactor for connecting the motor directly to the power line,

-a control unit for controlling the current limiting element and the bypass contactor,

characterized in that the device comprises at least one variable reactor with a main winding and a control winding, where the main winding constitutes the current limiting element in the start line, and the control winding together with means for regulating the current flowing in the control winding constitute means for controlling the reactance of the current limiting element.

2. Device according to claim 1, characterised in that the variable reactor comprises a ferromagnetic core, and the main winding and the control winding are wound around said core so that the magnetic field created by the main winding is orthogonal to the magnetic field created by the control winding.

3. Device according to any of claims 1-2, characterised in that the control winding's current regulating means are implemented as a half controlled, single-phase rectifier with free wheeling diode as power source for the control current.

4. Device according to any of claims 1-3, characterised in that the control winding's current regulating means are adapted to increase the current in the control winding from a start value to a final value.

5. Device according to any of claims 1-4, characterised in that the control unit comprises a timer device to trigger closing of the bypass contactor after a predetermined time has elapsed.

6. Device according to any of claims 1-5, characterised in that the control unit comprises a device for measuring current in the main winding.

7. Device according to any of claims 1-6, characterised in that the control unit is adapted to control the impedance of the variable reactor to perform a soft stop.

8. Device according to any of claims 1-2,
c h a r a c t e r i s e d i n that the control winding's current regulating means are adapted to decrease the current in the control winding from a start value to a final value.

9. Device according to claim 1,
c h a r a c t e r i s e d i n that the control winding's current regulating means are implemented as a H bridge IGBT device with free wheeling diode on each IGBT, the H bridge powered from a dc voltage.

10. Device according to claim 9,
c h a r a c t e r i s e d i n that that said DC voltage is a rectified voltage from the control voltage supply.

11. Device according to claims 9 or 10,
c h a r a c t e r i s e d i n that the control winding is located between the two half bridges so that the current delivered to the control winding can be switched in both directions through the winding and the control unit is equipped with a current measurement device to monitor the current in the control winding current flowing in the control winding be monitored for optimum control of motor current.

12. Device according to claim 11,
c h a r a c t e r i s e d i n that the H bridge current controller and monitor is coordinated with a current measurement of the motor current to control the motor current according to the demand of torque needed on the motor axis.

13. Method for connecting an asynchronous motor to a power line by means of at least one current limiting element arranged between the motor and the power line, comprising:

-connecting the motor to the power line through a start line comprising a variable reactor with a main winding and a control winding, where the variable reactor's main winding constitutes the current limiting element in the start line,

-gradually reducing the reactance of the main winding of the variable reactor by increasing the current flowing in the control winding of the variable reactor, and

-connecting the motor directly to the power line through a bypass line when one or more predefined conditions have been fulfilled.

14. Method according to claim 13,
c h a r a c t e r i s e d i n that the control winding's current is increased from a start value to a final value.

15. Method according to any of claims 13-14,
c h a r a c t e r i s e d i n that the control unit comprises a timer device to trigger connection of the motor directly to the power line after a predetermined time has elapsed.

16. Method for disconnecting an asynchronous motor from a power line by means of at least one current limiting element arranged between the motor and the power line, comprising, in a state where the motor is connected to the power line through a line comprising a variable reactor with a main winding and a control winding and the variable reactor's main winding constitutes the current limiting element in the start line:

-gradually increasing the reactance of the main winding of the variable reactor by decreasing the current flowing in the control winding of the variable reactor, and

-disconnecting the motor from the power line when one or more predefined conditions have been fulfilled.

17. Method according to claim 16,
c h a r a c t e r i s e d i n that it comprises decreasing the control winding's current from a start value to a final value.

18. Method according to any of claims 16-17,
c h a r a c t e r i s e d i n that the control unit comprises a timer device to trigger disconnection of the motor from the power line after a predetermined time has elapsed.

19. Method according to any claims 13-18, characterised in that the variable reactor comprises a ferromagnetic core, and the main winding and the control winding are wound around said core so that the magnetic field created by the main winding is orthogonal to the magnetic field created by the control winding.

20. Method according to any of claims 13-19,
c h a r a c t e r i s e d i n that the control winding's current is regulated by means of a half controlled, single-phase rectifier with free wheeling diode as power source for the control current.

21. Method according to any of claims 13-20,
c h a r a c t e r i s e d i n that it comprises measuring current in the main winding.

22. Method according to claim 13-21,
c h a r a c t e r i s e d i n that the control winding's current regulating means are implemented as a H bridge IGBT device with free wheeling diode on each IGBT, the H bridge powered from a dc voltage.

23. Method according to claim 22,
c h a r a c t e r i s e d i n that that said DC voltage is a rectified voltage from the control voltage supply.

24. Method according to claims 22 or 23,
c h a r a c t e r i s e d i n that the control winding is located between the two half bridges so that the current delivered to the control winding can be switched in both directions through the winding and the control unit is equipped with a current measurement device to monitor the current in the control winding current flowing in the control winding be monitored for optimum control of motor current.

25. Method according to claim 24,
c h a r a c t e r i s e d i n that the H bridge current controller and monitor is coordinated with a current measurement of the motor current to control the motor current according to the demand of torque needed on the motor axis.

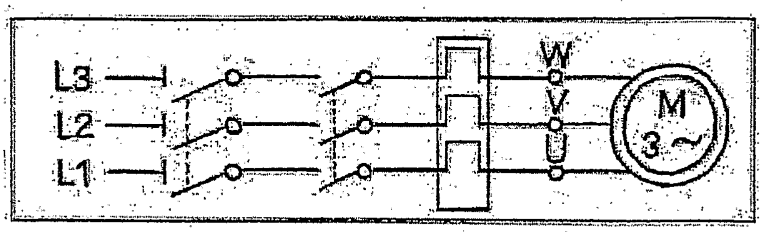


Fig. 1

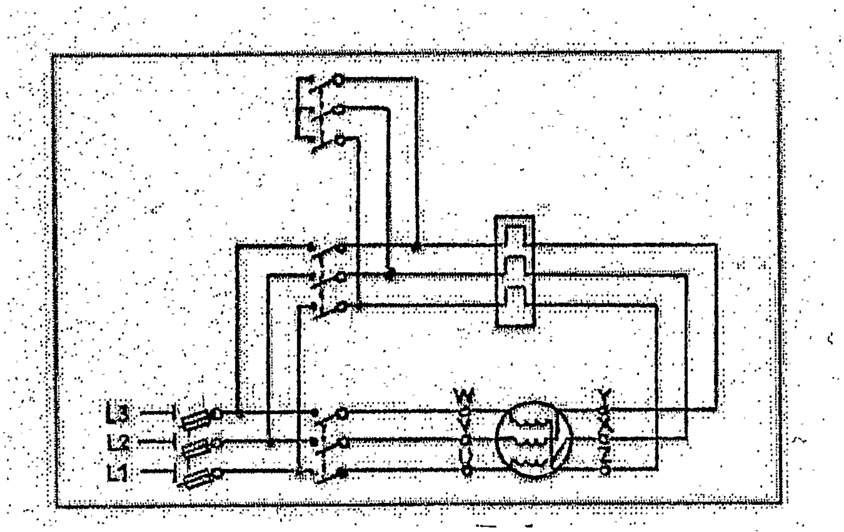


Fig. 2

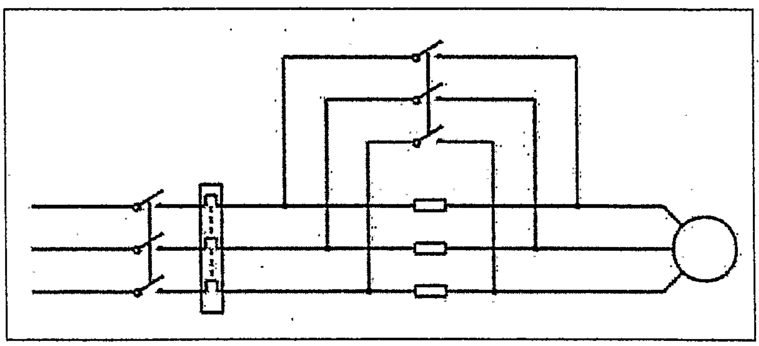

Fig. 3

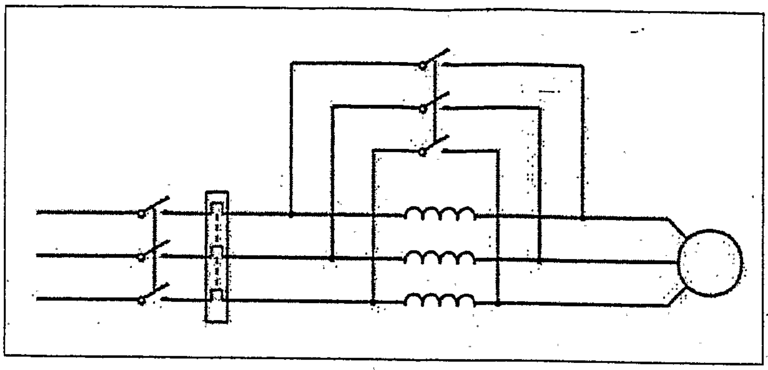

Fig. 4

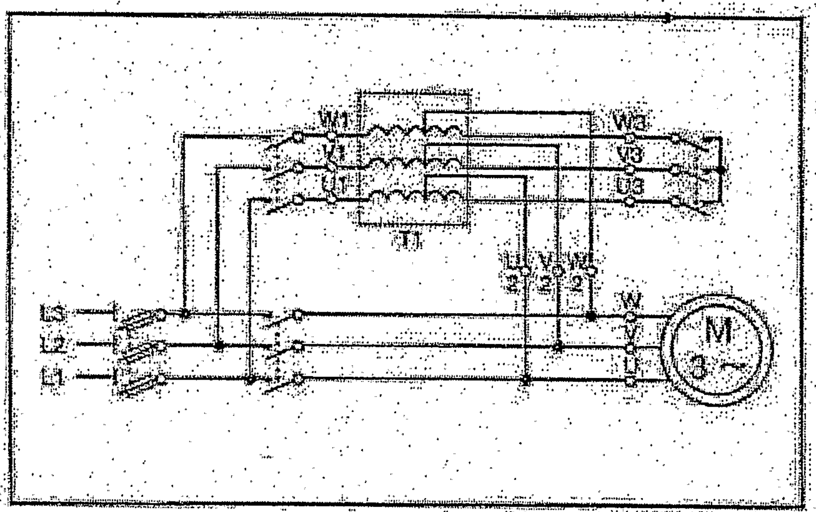


Fig. 5

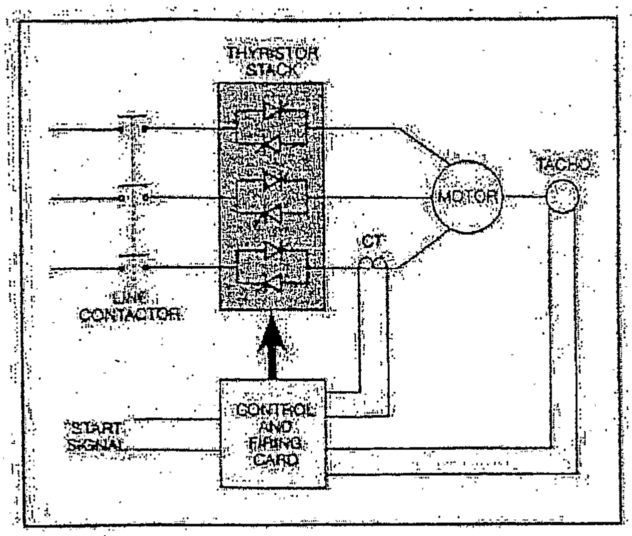
THYRISTOR STACK
MOTOR
TACHO
CT
LINE CONTACTOR
START SIGNAL
CONTROL AND FIRING CARD

Fig. 6

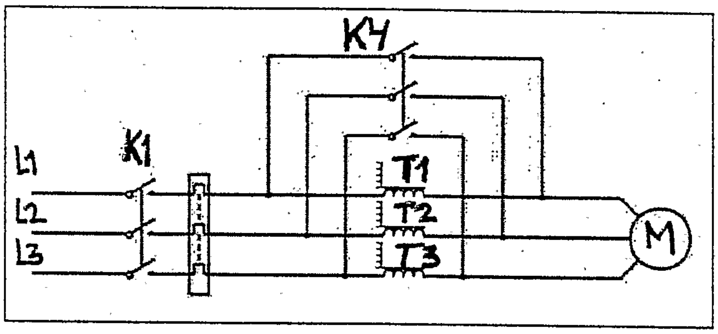
K4
L1
L2
L3
K1
T1
T2
T3
M

Fig. 7

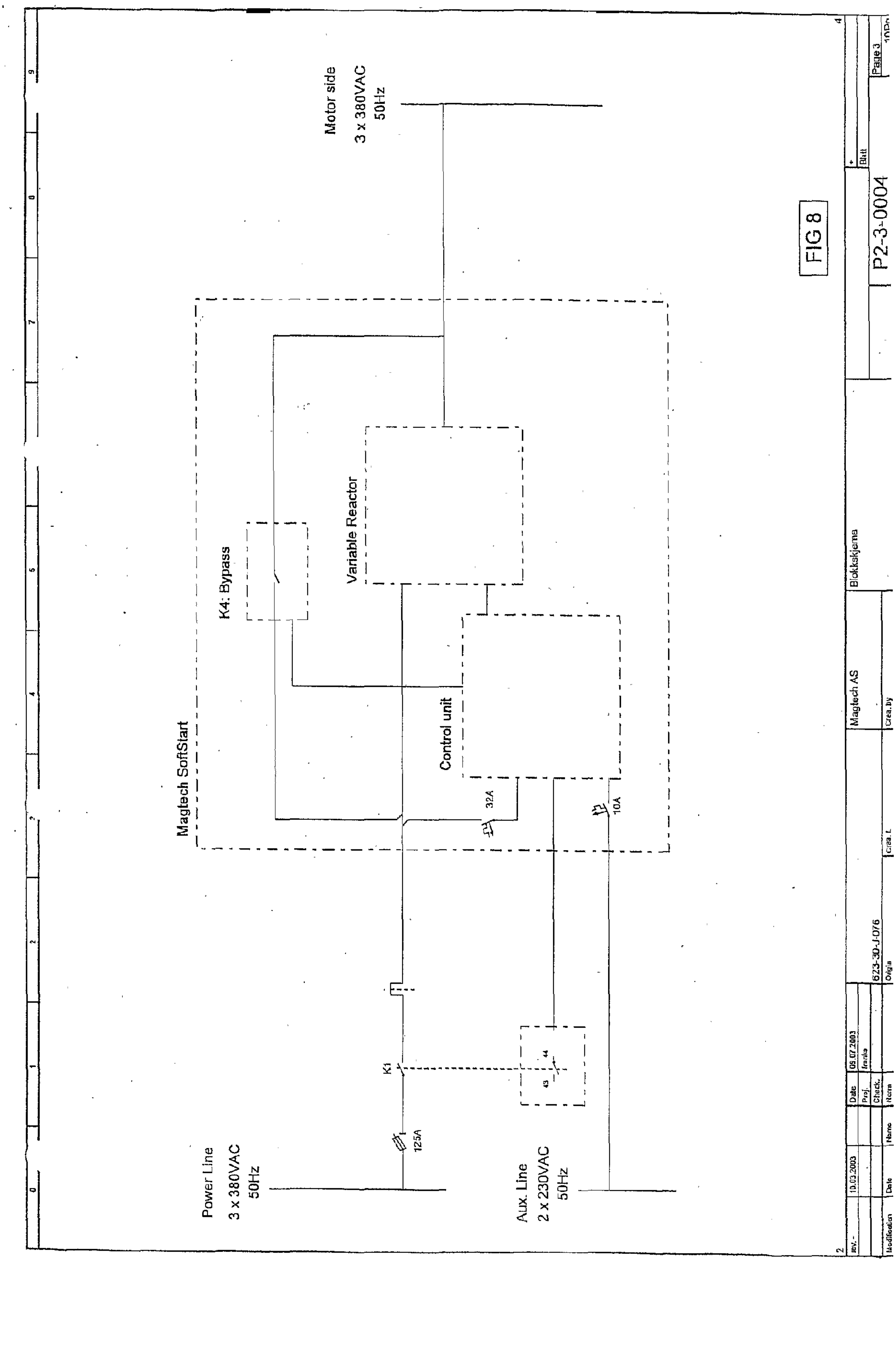
Motor side
3 x 380VAC
50Hz
Magtech SoftStart
K4: Bypass
Variable Reactor
Control unit
32A
10A
K1
125A
Power Line
3 x 380VAC
50Hz
Aux. Line
2 x 230VAC
50Hz
P2-3-0004
Blokkskjema
Magtech AS

FIG 8

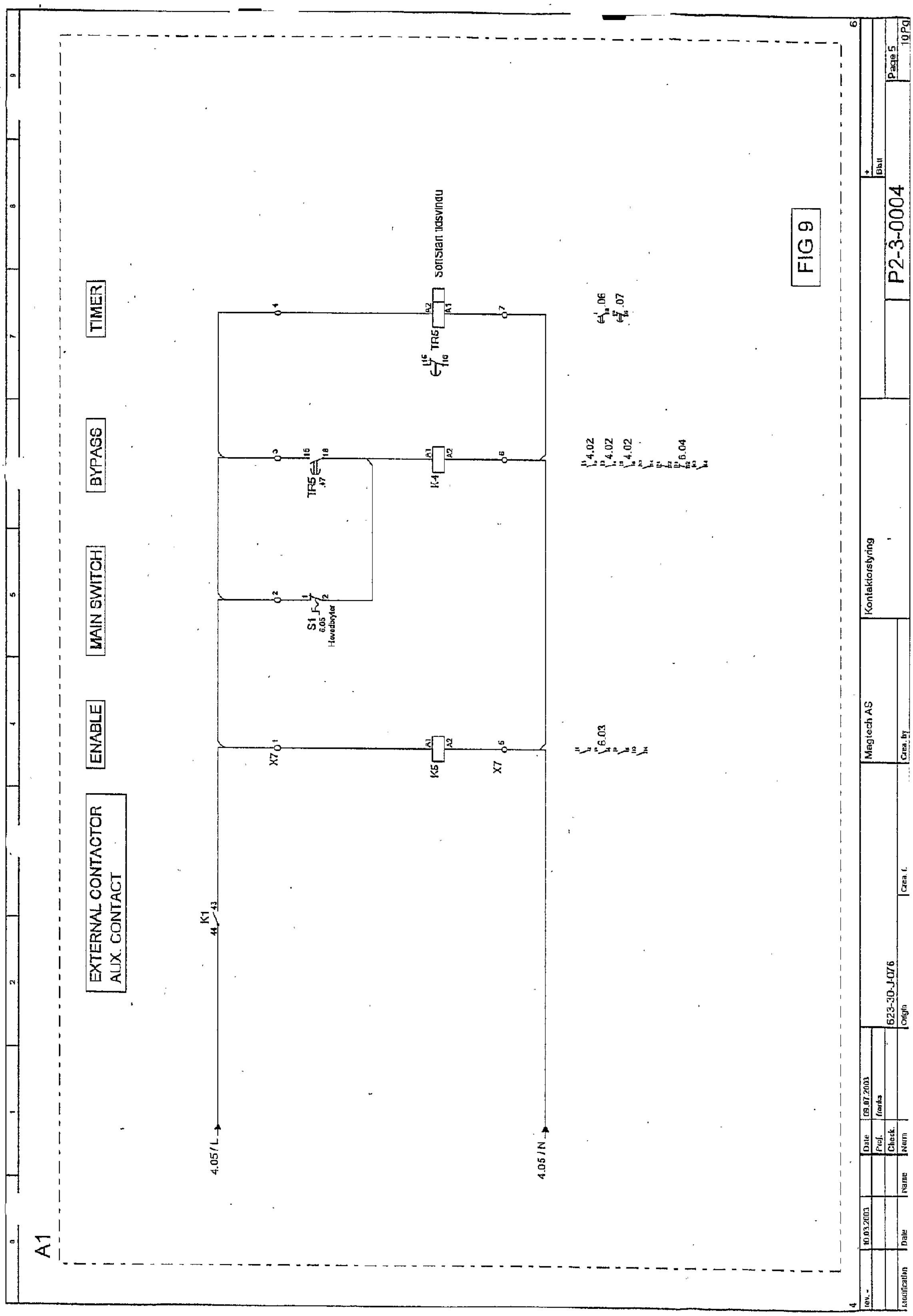
EXTERNAL CONTACTOR
AUX. CONTACT
ENABLE
MAIN SWITCH
BYPASS
TIMER
K1
4.05 / L
4.05 / N
X7
K5
K4
TR5
S1
Hovedbryter
Magtech AS
Kontaktorstyring
623-30-J-076
P2-3-0004
A1

FIG 9

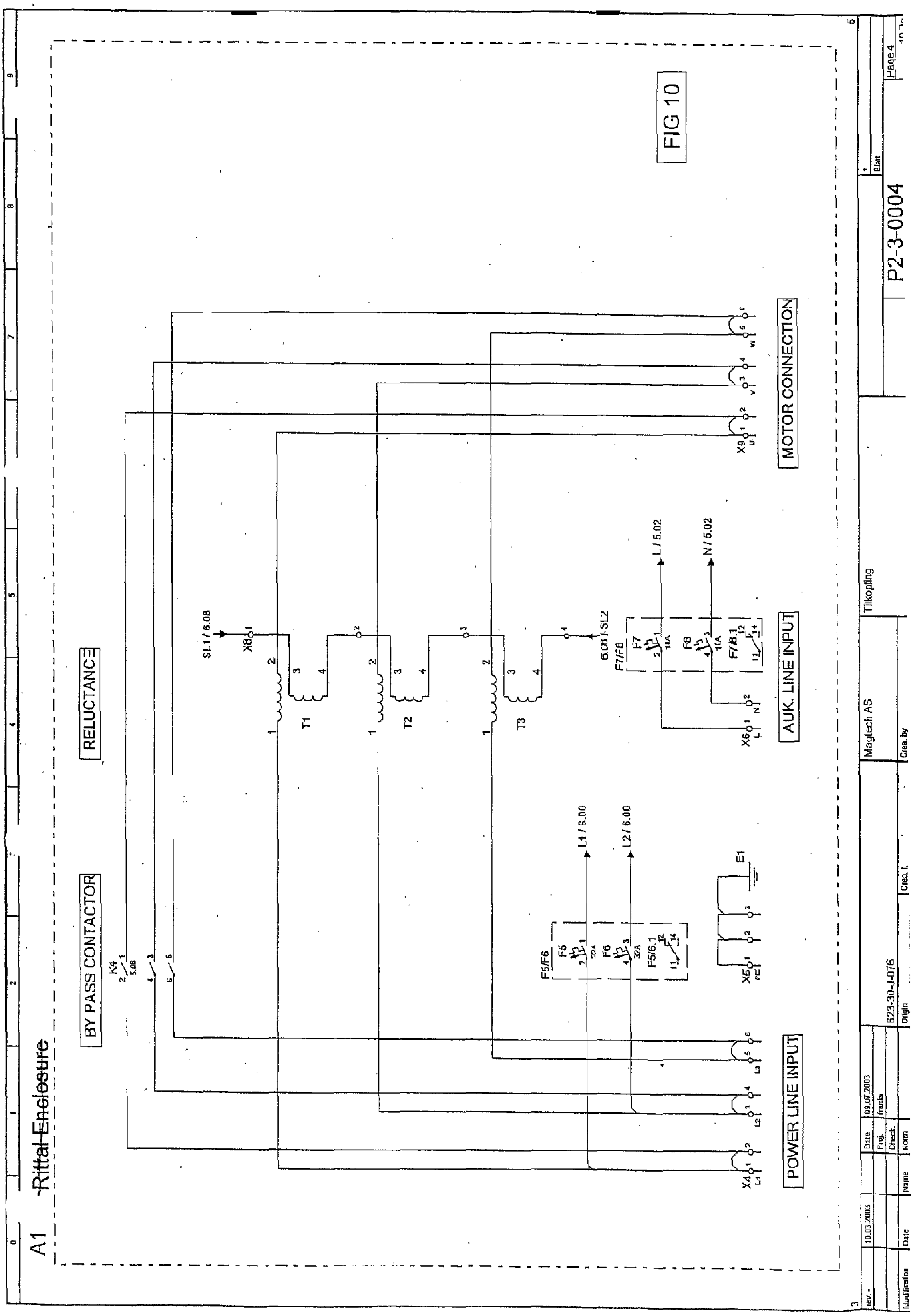
FIG 10
A1
Rittal Enclosure
BY PASS CONTACTOR
RELUCTANCE
POWER LINE INPUT
MOTOR CONNECTION
AUK. LINE INPUT
T1
T2
T3
L1 / 6.00
L2 / 6.00
L / 5.02
N / 5.02
SL1 / 6.08
6.08 / SL2
F5/F6
F7/F8
K4
X4
X5
X6
X8
X9
E1
P2-3-0004
Magtech AS
Tilkopling
Page4

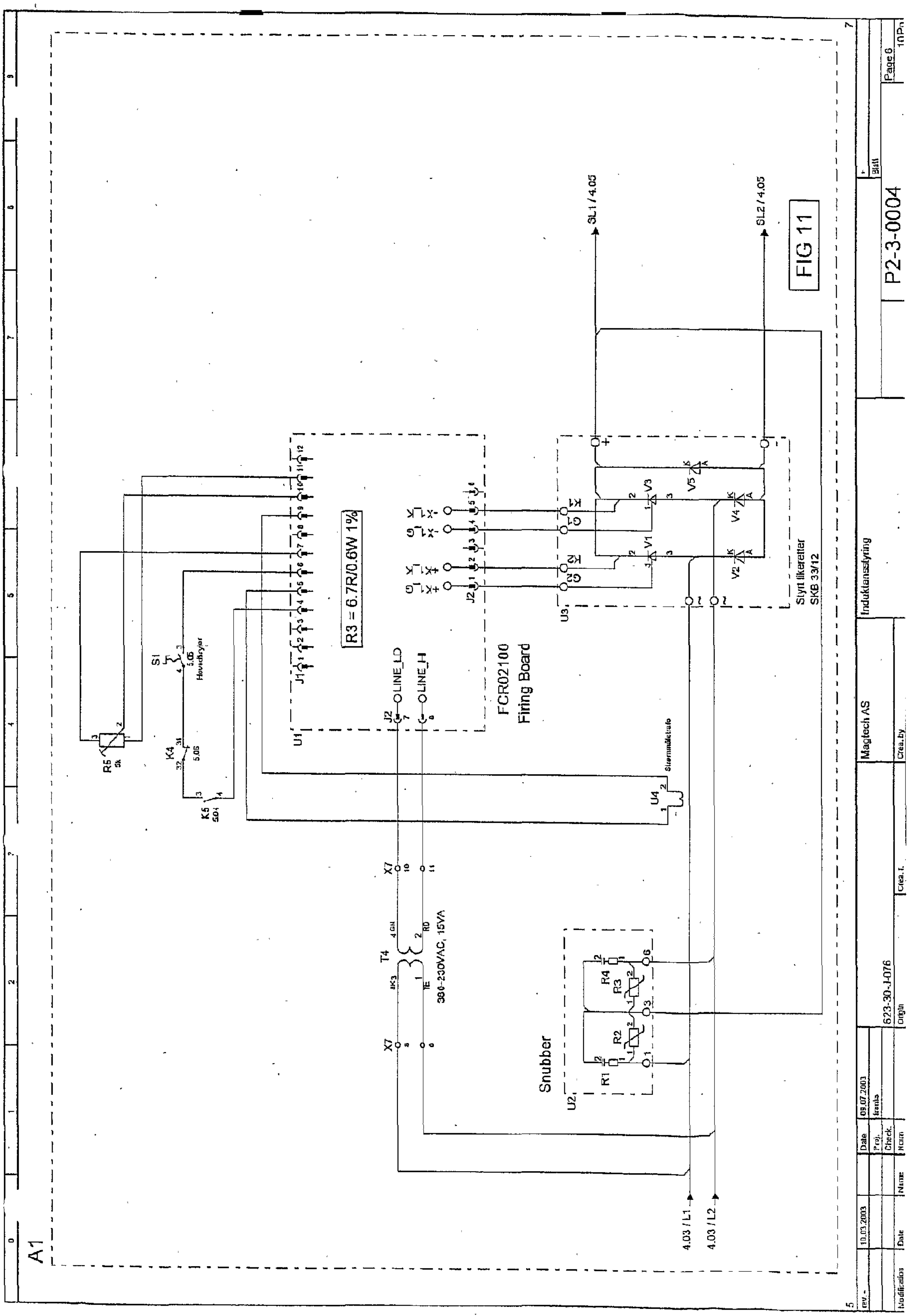
A1
FCR02100
Firing Board
R3 = 6.7R/0.6W 1%
Snubber
Styrt likeretter
SKB 33/12
380-230VAC, 15VA
SL1 / 4.05
SL2 / 4.05
4.03 / L1
4.03 / L2
Induktansstyring
Magtech AS
P2-3-0004
623-30-J-076

FIG 11

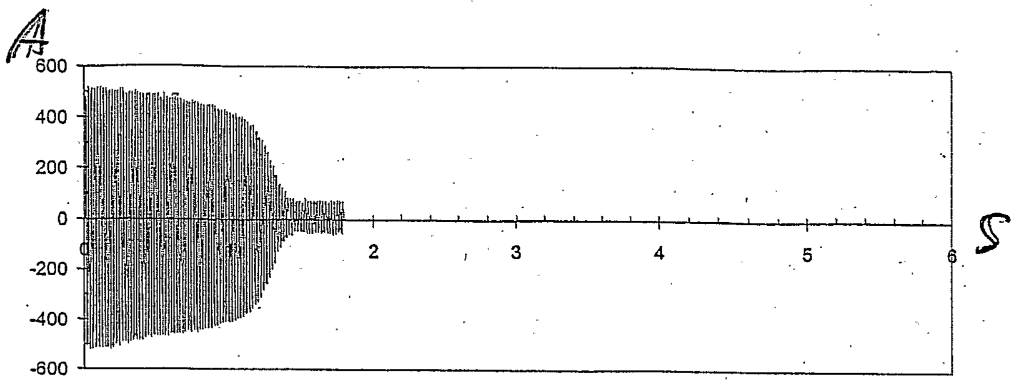
A
600
400
200
0
-200
-400
-600
0
2
3
4
5
6
S

Fig. 12

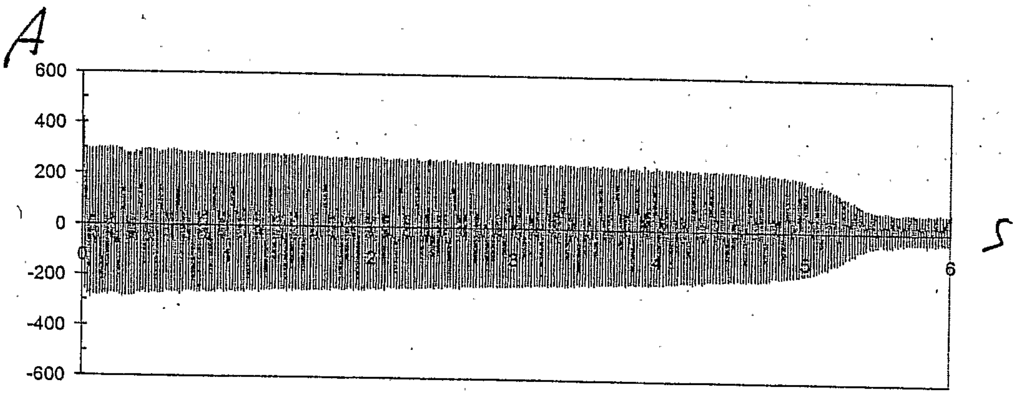
A
600
400
200
0
-200
-400
-600
0
2
5
6
S

Fig. 13

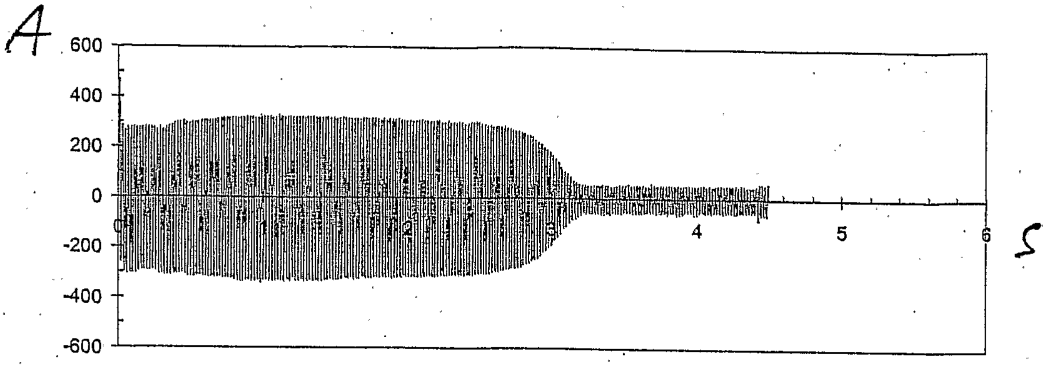
A
600
400
200
0
-200
-400
-600
0
1
2
3
4
5
6
S

Fig. 14

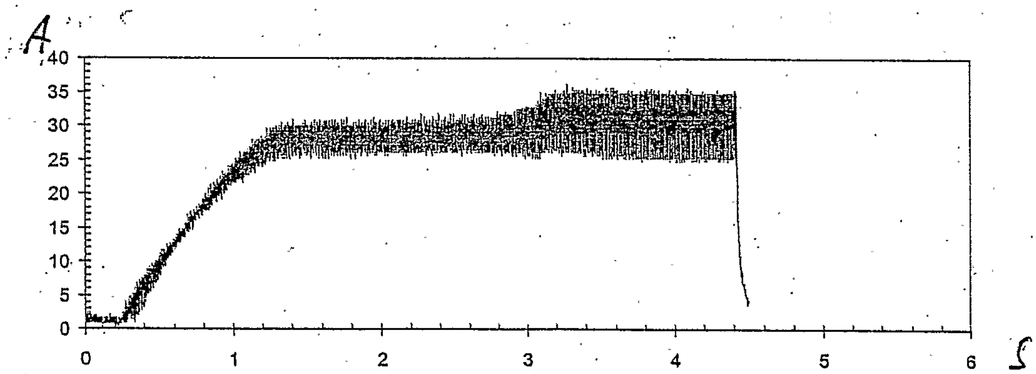
A
40
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
S

Fig. 15

# INTERNATIONAL SEARCH REPORT

International Application No
PCT/NO2004/000224

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 7 G05F1/32 H02P1/28 H02P3/18

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H02P H01F G05F H02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
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| Y | WO 01/90835 A (HAUGS ESPEN ; MAGTECH AS (NO); STRAND FRANK (NO)) 29 November 2001 (2001-11-29) cited in the application page 1, line 20 - page 1, line 22 page 5, line 8 - page 5, line 32; figures 1a,56,57,67a | 1-8, 13-21 |
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 11 November 2004 | 22/11/2004 |

| Name and mailing address of the ISA | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL – 2280 HV Rijswijk<br>Tel. (+31–70) 340–2040, Tx. 31 651 epo nl,<br>Fax: (+31–70) 340–3016 | Braccini, R |

# INTERNATIONAL SEARCH REPORT

International Application No
PCT/NO2004/000224

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
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Information on patent family members

International Application No
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| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
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