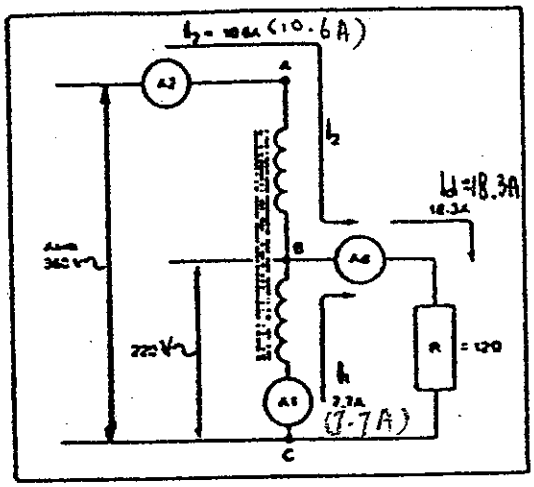
Motor control

Autotransformer starters (part 1)

PRINCIPLE

Introduction

In order to understand the operation of an autotransformer, carry out the following experiment :



Take an autotransformer (or AT*) with a power S = 500 VA supplied at 380 V

Connect a resistance R of 12 Ω across the 220 V tapping as shown in the diagram on the left.

IN THE STEADY STATE, read :
- a current I_1 on ammeter A1 = 7,7 A
- a current I_2 on ammeter A2 = 10,6 A
- a current I_d on ammeter Ad = 18,3 A

This enables the following points to be highlighted :

1) The autotransformer operates at constant power, i.e.

The power taken by the resistance is
$P = I^2R = 18{,}3^2 \times 12 = 4018$ W

The power taken from the mains supply is
$P = UI = 380 \times 10{,}6 = 4018$ W

2) The transformer ratio k is given by the relationship :

$$k = \frac{\text{tapped voltage}}{\text{supply voltage}} = \frac{220\ V}{380\ V} = 0{,}58$$

this ratio will always be less than 1

3) The current in the resistance, Id will be given by

$$Id = \frac{U}{R} = \frac{220}{12} = 18{,}3\ A$$

4) The ratio :

$$\frac{I_2 \text{ (line current drawn from the mains)}}{Id \text{ (current flowing in the resistance)}} = k \text{ (transformer ratio < 1)}$$

giving

$I_2 = Id \times k = 18{,}3 \times 0{,}58 = 10{,}6$ A

* In this document AT is short for autotransformer.

5) The ratio of line current I_2 to the current ID which flows through the resistance R supplied at full voltage (380 V) is equal to the square of the transformer ratio.

$$ID(\text{at full voltage}) = \frac{U}{R} = \frac{380}{12} = 31{,}6\ A$$

and

$$\frac{I2}{ID} = \frac{10{,}6}{31{,}6} = 0{,}33 \text{ and } K2 = \left(\frac{220}{380}\right)^2 = 0{,}33$$

6) Note that :

$I_1 + I_2 = Id$, i.e.

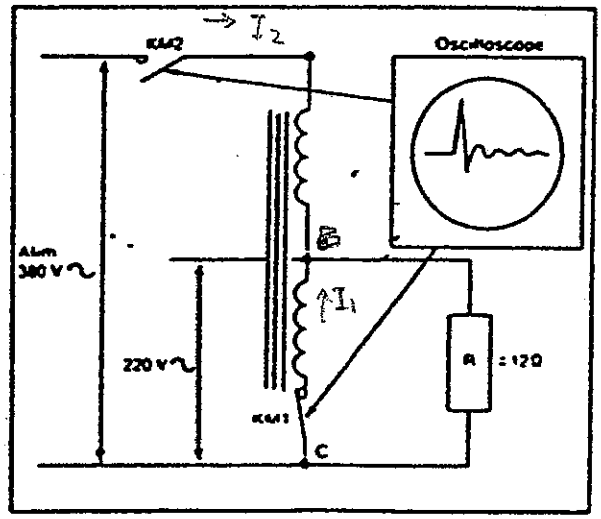
$7{,}7 + 10{,}6 = 18{,}3$ A giving

current flowing in branch BC of the AT has a value of :

$I_1 = Id - I_2$

IN TRANSIENT OPERATION

In the previous circuit, replace ammeters A1 and A2 by contactors KM1 and KM2 and notice what happens when KM2 closes, with KM1 already closed.



As KM2 closes, measure the transient current

$\hat{I} = 48$ A

which is the same on-load or off-load.

This same current peak can be found in branch circuit BC flowing through the pole of contactor KM1.

Calculate the ratio of $\frac{\hat{I}}{In}$ where

$$In = \frac{S}{U} = \frac{500}{380} = 1{,}31 \text{ A giving}$$

$$\frac{\hat{I}}{In} = \frac{48}{1{,}31} = 36$$

Note that this is a transformer being used as an autotransformer for the purposes of this experiment - in other words it does not have an air gap.
The ATs used for motor starting normally have an air gap which is either calculated or arbitrary, and which has the effect of considerably reducing the peak current at switch on.

Autotransformer starting

The system consists of provisionally reducing the voltage applied to the motor by the use of an AT.
The energy losses during starting are negligible.

Using k as the transformer ratio ($k < 1$), the voltage at the motor terminals is :

$k U_N$	U_N : mains voltage

As the torque of an asynchronous motor is proportional to the square of the voltage, the torque during starting will be reduced to a value given by the equation :

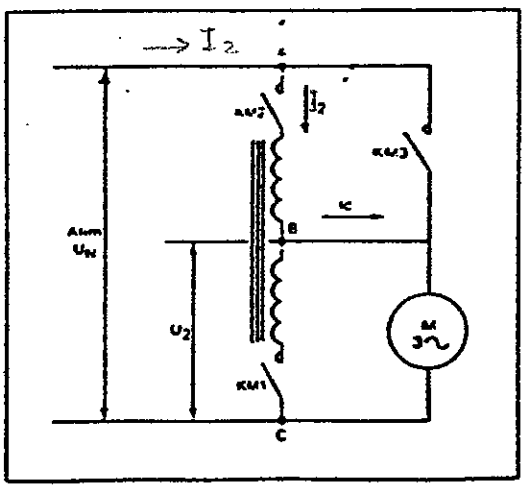
$Td = TD \times k^2$	Td : starting torque at reduced voltage

TD: starting torque at full voltage
k : transformer ratio

EXAMPLE : the typical value of full voltage torque TD being of the order of 1,5 T_N it can be shown, for example, that for a transformer ratio k = 0,65 that the starting torque at reduced voltage will be :

$$Td = 1{,}5\ T_N \times 0{,}65^2 = 0{,}63\ T_N$$

where T_N is the rated motor torque at full voltage



ELEMENTARY CIRCUIT DIAGRAM

U_N : supply voltage

$\frac{U_2}{U_N}$ = k the transformer ratio

I_2 : line current during starting

$U_2 = kU_N$

Taking ID to be the starting current at full voltage, the current taken by the motor during autotransformer starting will be :

$$Id = ID \times k$$

If the losses and the magnetising current of the AT are ignored, this means that the output power is the same as the input power.

For three phase supplies :

$k U_N \times kID \times \sqrt{3} = U_N \times I_2 \times \sqrt{3}$ whence

$I_2 = k^2 ID$

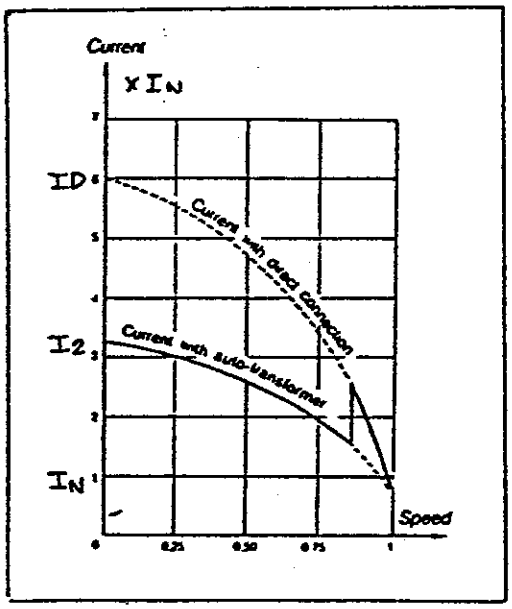
EXAMPLE : a typical value of starting current ID is $6I_N$.

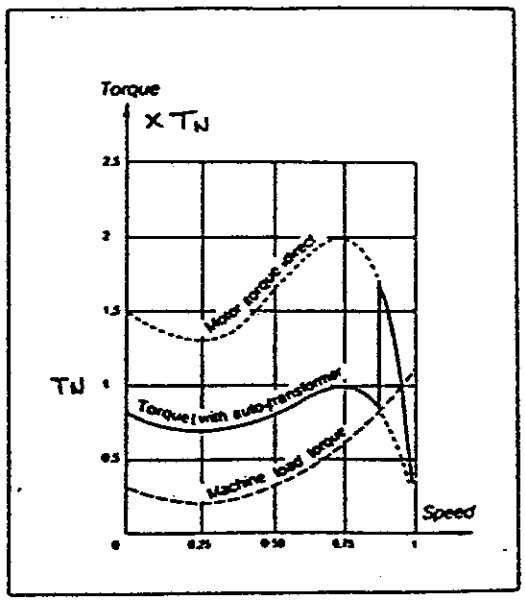
For a transformer ratio of 0,65, for example, this would produce a line current of :

$I_2 = 6I_N \times 0{,}65^2 = 2{,}53\ I_N$

Typical values for autotransformer starting

Example of curves for a ratio k = 0,73

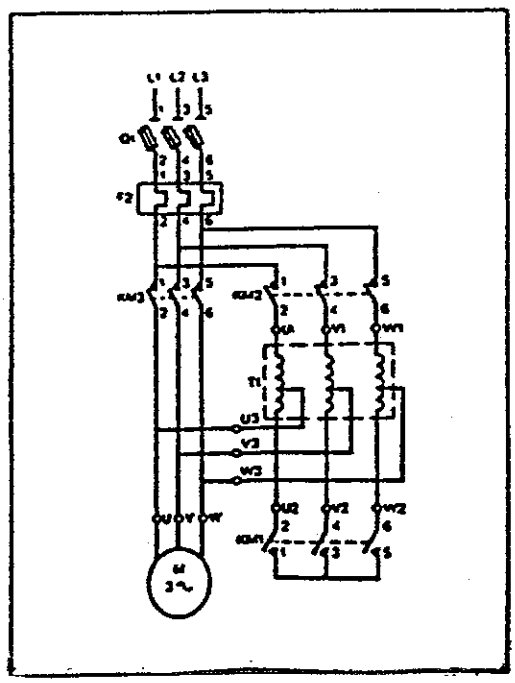




TYPICAL CIRCUIT

Composition of an autotransformer starter

POWER CIRCUIT



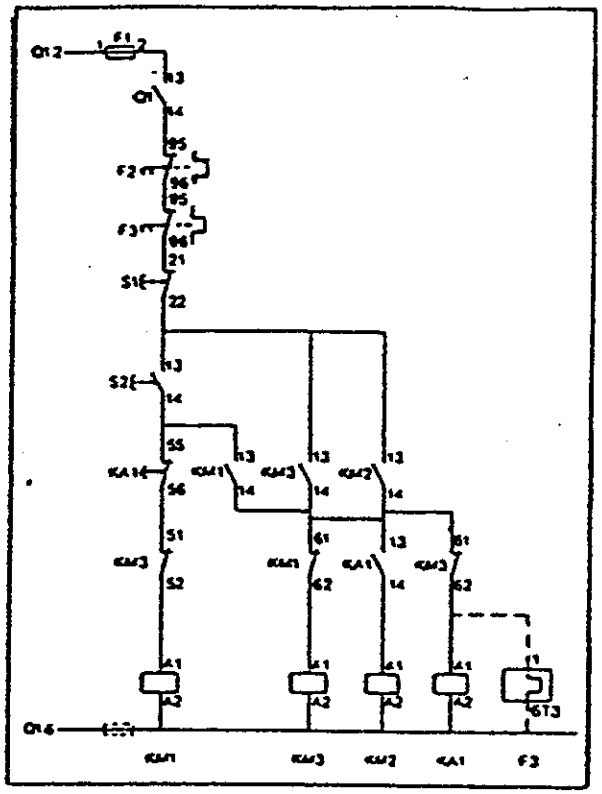
Operation of the power circuit

Manual closing of Q1.
Closing of KM1 : star connection of the autotransformer
Closing of KM2 : supply connected to the autotransformer - the motor starts.
Opening of KM1 : opening of autotransformer star connection - the motor is temporarily fed through part of the autotransformer windings.
Closing of KM3 : direct connection of the motor to the supply.
Opening of KM2 : disconnection of the autotransformer.

- Special features

Q1 : rated for the motor I_N
F2 : rated for the motor I_N

CONTROL CIRCUIT



Operation of the control circuit

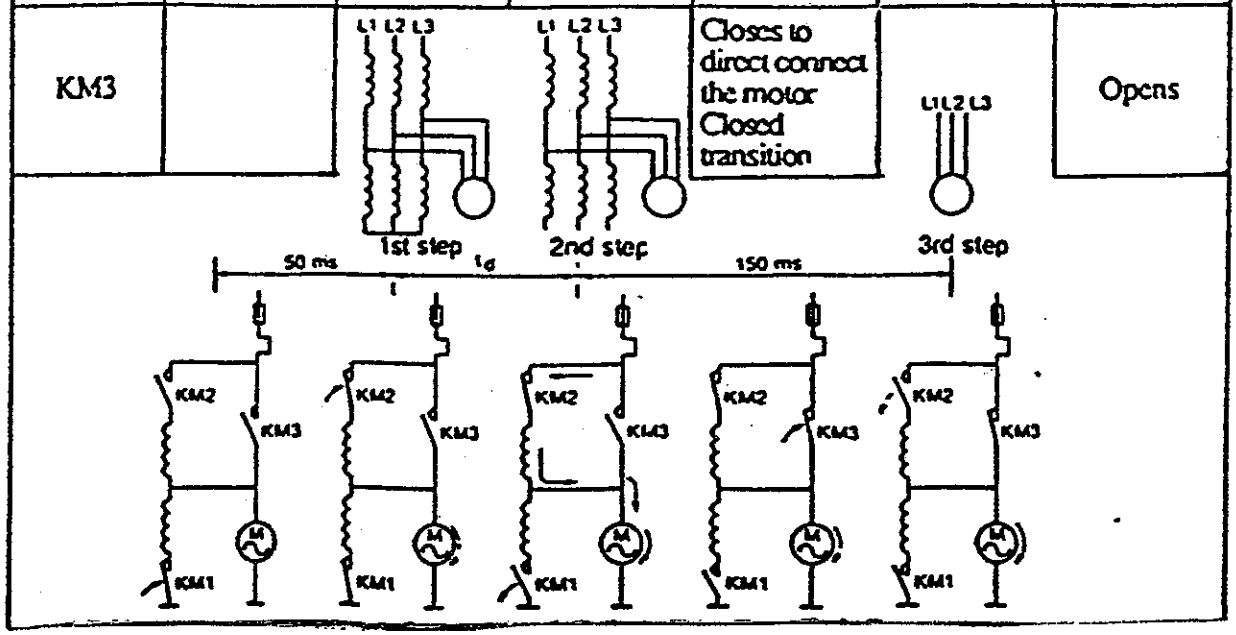
Actuation of S2.
Closing of KM1.
Interlocking of KM3 by KM1 (61-62).
Closing of KA1 by KM1 (13-14), and connection of thermal time delay relay F3.
Closing of KM2 by KA1 (13-14).
Hold in of KM2 (13-14).
Opening of KM1 by KA1 (55-56).
Closing of KM3 by KM1 (61-62).
Interlocking of KM1 by KM3 (51-52).
Hold in of KM3 (13-14).
Opening of KA1 by KM3 (61-62).
Disconnection of F3 by KM3 (61-62).
Opening of KM2 by KA1 (13-14).
Stop : actuation of S1.

• Special features :

F3 : thermal time delay relay ensuring protection of the autotransformer against too frequent or incomplete starting.

SEQUENCE OF OPERATIONS

Operation	1st	2nd	3rd	4th	5th	
KM1	Closes on no-load Star connection		Opens star connection Motor runs with series inductance			
KM2		Closes to connect the AT Motor starts			Opens on no-load Disconnection of the AT	
KM3				Closes to direct connect the motor Closed transition		Opens



Note that the current flowing in the motor is not interrupted at any time (closed transition).

Nevertheless, to avoid slowing down, the inductance should be small during the 2nd step.

This can be shown by approximation, ignoring the phase difference between the inductance and motor voltages.

Assume that starting occurs at 0,65 of the mains voltage and that the motor, at the time of changeover, is taking rated current.

To avoid slowing down, the inductance through which the current is flowing must absorb 0,35 of the voltage, i.e. the flux in the magnetic circuit remains constant. Consequently, the autotransformer operates normally, in other words with all its windings, not just 35 % of them, taking a magnetising current of 0,35 of the rated motor current.

To respect this condition, the autotransformer must be specially built to include an air gap in the magnetic circuit. Naturally, this high magnetising current creates a corresponding increase in the current taken from the mains during starting.

The autotransformer often has three tappings, at 0,50, 0,65 and 0,80 of rated voltage, to enable adjustment. This is often an unnecessary complication, as the 0,50 tapping, which produces a starting torque lower than that for star-delta starting, could normally be eliminated. In general it is the 0,65 tapping that corresponds to the most frequently encountered applications. The 0,80 tapping can be useful if the resistive torque of the driven machine varies during starting according to a little known law.

Autotransformers are normally of three phase construction. Sometimes, for economic reasons, they are constructed using two windings in V connection. This produces unbalanced voltage drops, which can cause problems under arduous starting conditions.

Selection criteria for autotransformer starters

ELECTRICAL

Starting at reduced voltage eliminates the high starting current drawn from the mains and limits this value to 1/2 that for direct-on-line starting (for $k = 0,7$ the value of $k^2 = 0,49$).

The line voltage drops are reduced in the same proportion.

MECHANICAL

The torque is reduced in the same proportion as the starting current, but remains relatively high.

If the different methods of reduced voltage starting are compared, as in the following table, this highlights :

1) For the same value of starting current, the torque is much higher with an autotransformer starter than with a primary resistance or solid state starter.

2) Although the ID/TD ratio is identical for both star-delta and autotransformer starting, the latter has the advantage of being able to adjust the voltage at the motor terminals and this can be used to adapt the motor torque curve to the driven machine.

	Full voltage	Reduced voltage			
		Primary resistance or solid state		AT	Star-delta
U at motor terminals	1	0,33	0,58	0,58 adjustable	0,58 fixed
ID line as multiple of I_N	6	2	3,5	2 $(0.58^2 \times 6)$	2
TD motor as multiple of T_N	1,5	0,16	0,5	0,5 $(0.58^2 \times 1.5)$	0,5

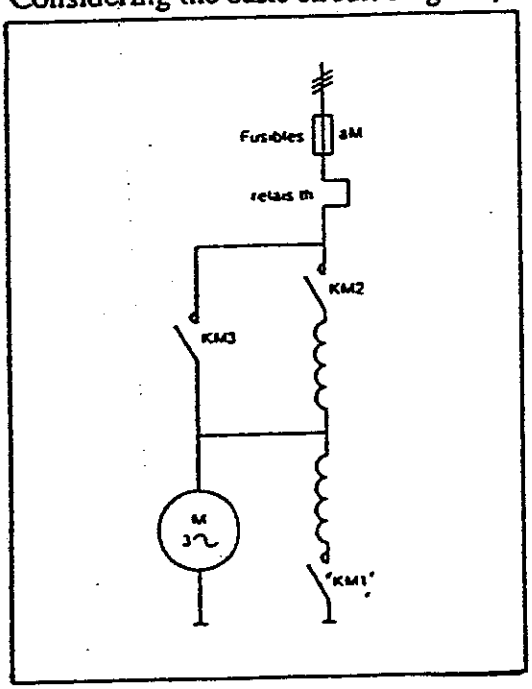
Typical applications

This type of starting can be used for high inertia machines
or
high powered machines with a relatively long starting time
(15 s, 30 s or even 60 s).

EXAMPLES

Crusher
Grinder
Compressor
Centrifuge
Wood saw
Conveyor belt for heavy materials
Escalator
High power turbo-exhauster, etc...

Considering the basic circuit diagram, below, in order to select :



- the rating of contactors KM1, KM2 and KM3,
- the rating of the thermal overload relay,
- the rating of the fuses,

It is essential to know :

- the power of the motor, P, in kW,
- the supply voltage, U_N, in volts,
- the control voltage,
- the full load current of the motor, I_N, in amps

- the starting current ID of the motor at full voltage, which gives :
- the ratio $\frac{ID}{I_N} = \rho$
- the transformer ratio of the AT
  $k < 1$
- the starting time, td, in seconds. It is normal to allow for two consecutive starts.
- the number of starts per hour (class of duty)

For the calculations, the following values are used :

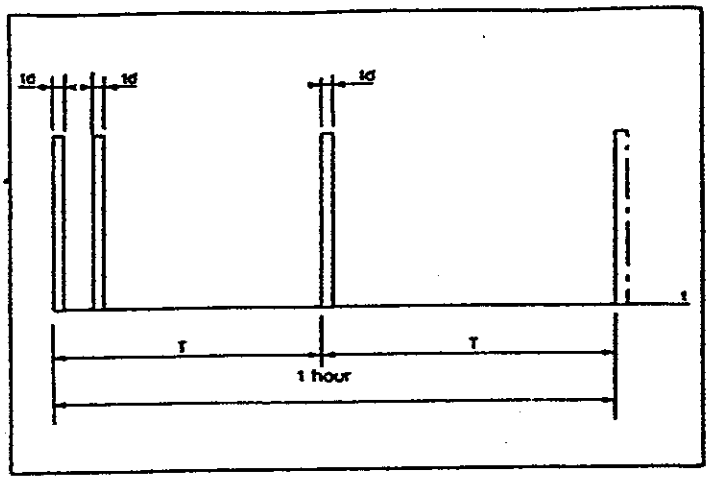
- ambient temperature ≤ 40 °C,

NOTE :

A certain difficulty of interpretation can arise concerning the calculation of the cycle time T.

EXAMPLE : Take 3 starts per hour including two consecutive starts.

The sequence must be interpreted as represented on the following diagram :



giving

$$T = \frac{3600}{2} = 1800\ s$$

To simplify the calculations, use 2 td as the starting time.

CONCLUSION

The choice of contactors KM1 and KM2 is based on the equivalent thermal current that they can carry during starting, providing that they can make or carry the transient peak of the autotransformer magnetising current.

Calculation of the equivalent current Ie AC1

To calculate this value, and to avoid complex calculations, use the simplified formula :

$$Ie\ AC1\ (contactor) = I \times Q$$

where

Ie AC1 = operational current of the selected contactor

I = starting current for time period td

Q = factor < 1 (see table, page 11).

take into account :

- the starting time td
- the pseudo thermal time constants of the contactor τe heating and τr cooling
- the cycle time T, use

$T \geq 600$ s for the D-range
$T \geq 1200$ s for the F-range

As a guide, the factor Q has a value given by :

$$Q = 1{,}7 \sqrt{\frac{1 - e^{-\frac{td}{\tau e}}}{1 - e^{-\left(\frac{td}{\tau e} + \frac{T - td}{\tau r}\right)}}}$$

- the choice of contactor is made by successive approximations (iterative method - see calculation example, page 6 part 2).

IMPORTANT NOTE
The Q factors given in the table are valid :

- For the D-range : 6 starts per hour, including 2 consecutive starts
- For the F-range : 3 starts per hour, including 2 consecutive starts

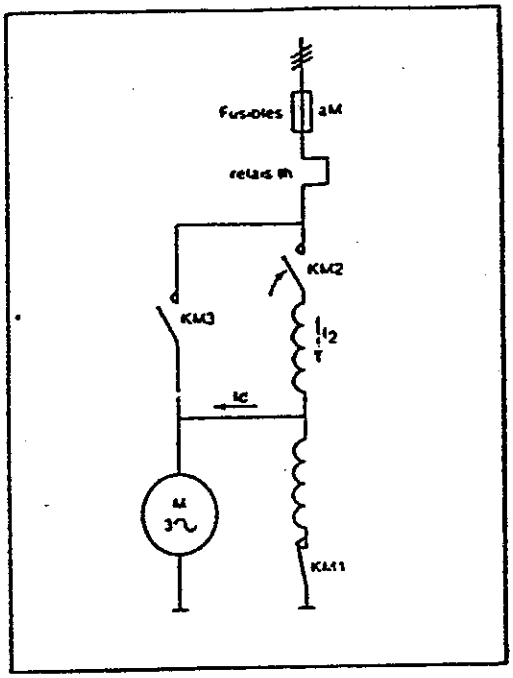
Table of Q factors

Type of contactor	Starting time td in s						
	5	10	15	20	30	45	60
D-range	0,17	0,21	0,25	0,28	0,34	0,39	0,42
FF, FG, FH	0,17	0,17	0,20	0,23	0,29	0,35	0,37
FJ, FK, FL	0,17	0,17	0,18	0,19	0,21	0,26	0,29
FX	0,25	0,25	0,26	0,27	0,28	0,32	0,35
BL	0,08	0,11	0,13	0,14	0,17	0,20	0,22
BM	0,13	0,15	0,18	0,20	0,24	0,29	0,33
BP	0,16	0,21	0,24	0,27	0,31	0,35	0,38
BR	0,18	0,23	0,27	0,30	0,34	0,39	0,43
$\sum \bar{x}$	0,16	0,19	0,21	0,23	0,27	0,32	0,35

* Calculations based on the values for short time current ratings shown in the 1987-88 General Catalogue.

Selection of KM2

The calculations are made for starting in stalled rotor condition (a severe case but one which could arise in operational circumstances).



On starting, the current taken by the motor at reduced voltage is given by :

$$Id = ID \times k$$

using $\frac{ID}{I_N} = p$

this gives :

$$Id = p\, I_N \times k$$

the current flowing in KM2, assuming the magnetising current of the AT to be equal to 0,25 I_N, is given by

$$I_2 = Id \times k + 0{,}25\, I_N \text{ whence}$$

$$I_2 = pI_N \times k^2 + 0{,}25\, I_N$$

putting :

$$p = \frac{ID}{I_N}$$

I_N : rated motor current

ID : starting current of the motor at full voltage

k : transformer ratio of the AT

During the starting time, current I_2 is flowing in contactor KM2 (an excessive value as the rotor is assumed to be locked).

The choice will therefore be made based the short time ratings taking into account the starting times and the class of duty (see § calculation of equivalent current Ie AC1, page 10).

Next make sure that the making capacity of the contactor is compatible with the magnetising current peak of the autotransformer which it is switching, using the relationship :

$$\text{MC of the contactor KM2} \times \sqrt{2} \geq \frac{2{,}5\, P_M}{U}$$

P_M : motor power in watts

U : mains voltage in volts

MC : making capacity (catalogue data) in amps (rms)

Now, using (by experience)

$$\text{Power of the AT} = \frac{P_M}{7}$$

and $\hat{I}\,(AT) = 30\ In\,(AT)$

This gives

$$In\,(AT) = \frac{P_M}{7 \times U \times \sqrt{3}} = \frac{P_M}{12\,U}$$

or

$$\hat{I}\,(AT) = 30\ In\,(AT) \quad \text{giving} \quad \hat{I}\,(AT) = \frac{30 P_M}{12\,U}$$

whence

$$\hat{I}\,(AT) = \frac{2{,}5\, P_M}{U}$$

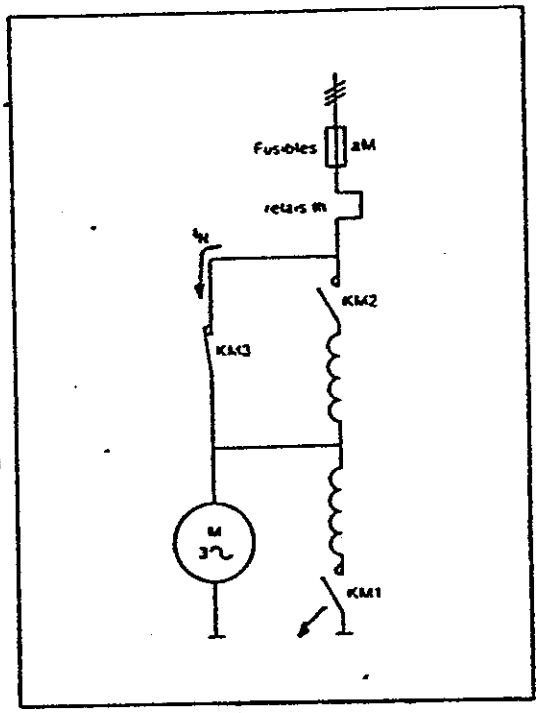
P_M : motor power in watts

U : mains voltage in volts

MC : making capacity (catalogue data) in amps (rms)

Selection of KM3

It is normal to rate this contactor for the I_N AC3 of the motor. This is for three reasons :



1) In spite of the closed transition, the contactor must be able to accept a current peak on closing, of between $2\sqrt{2}$ and $9\sqrt{2}$ of the rated motor current I_N

   This value depends on the air gap of the autotransformer, which itself affects the value of the inductance which causes a greater or lesser slowing down of the motor.

   For a calculated air gap (ideal case) the peak would be negligible ($\simeq 2\sqrt{2}\ I_N$).

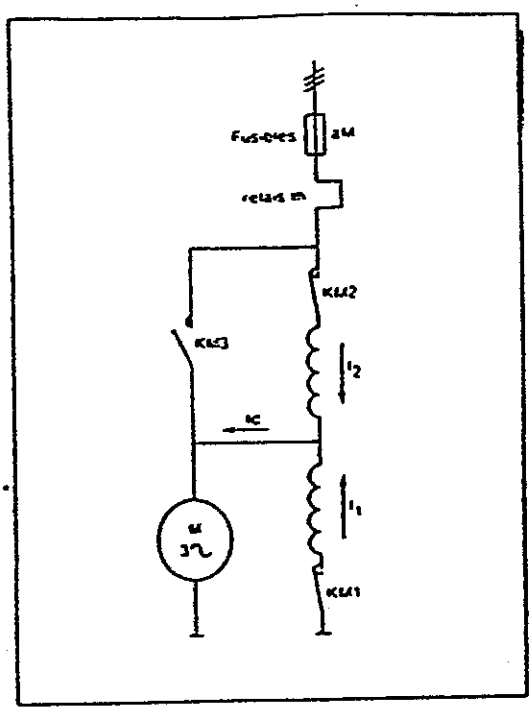
- For a random value of air gap the peak would be average ($\simeq 6\sqrt{2}\ I_N$). (the most common case)
- For zero air gap, the peak will be a maximum ($\simeq 9\sqrt{2}\ I_N$), but fortunately such cases are comparatively rare.

2) In order to retain "type 2" coordination between the fuses, the contactor and the overload relay.

3) In order to be able to break the AC4 current of the motor, if required, should the starting be carried out under locked rotor conditions.

Selection of KM1

Component selection



The value of current flowing in the star contactor KM1 is given by :

$I_1 = Id - I_2$

i.e.

$I_1 = (p \times I_N \times k) - (p \times I_N \times k^2 + 0{,}25\ I_N)$

simplifying

$$I_1 = p \times I_N \times k\,(1 - k) - 0{,}25\ I_N$$

I_1 : the current flowing in contactor KM1

I_N : rated motor current

k : transformer ratio of the AT (< 1)

p : the ratio $\frac{ID}{I_N}$

ID . : starting current of the motor at full voltage.

The choice of this contactor is therefore also based on the short time ratings taking into account the starting times and the class of duty (see § calculation of equivalent current Ie AC1, page 10).

Next make sure that the making capacity of this contactor is compatible with the magnetising current peak of the autotransformer which flows through it in the closed condition.

Use the relationship :

$$\text{MC of the contactor KM2} \times \sqrt{2} \geq \frac{2{,}5\ P_M}{U}$$

Mechanical interlock

In certain countries, local practice is to fit a mechanical interlock between contactors KM1 and KM3.
Where this is the case, it is essential to verify the technical feasability of fitting a mechanical interlock between two different size contactors. If this is not possible, use two contactors of identical rating for KM1 and KM3.

Bibliography

- "Study of autotransformer starters"
  Telemecanique - CANADA.

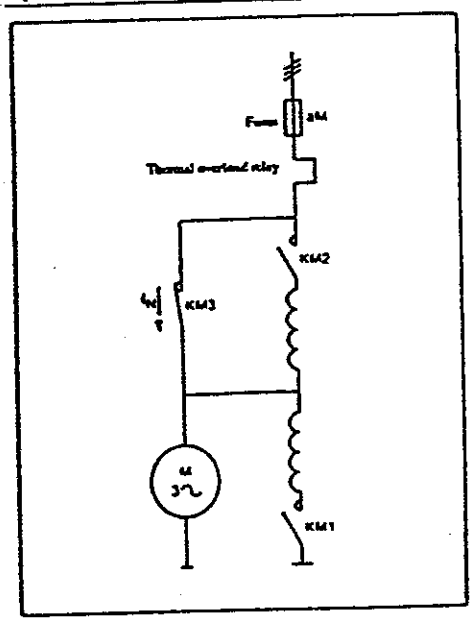
- "Electrical equipment for industrial automation"
  Michel Chevalier.

Motor control

Autotransformer starters (part 2)

Protection

a) AGAINST SHORT-CIRCUITS



This is the role of the fuses located on the incoming side of the starter.
They will be rated at the I_s value of the motor.

b) AGAINST OVERLOADS

This is the role, either of the thermal overload relay, or of a multifunction protection relay (usually electronic).

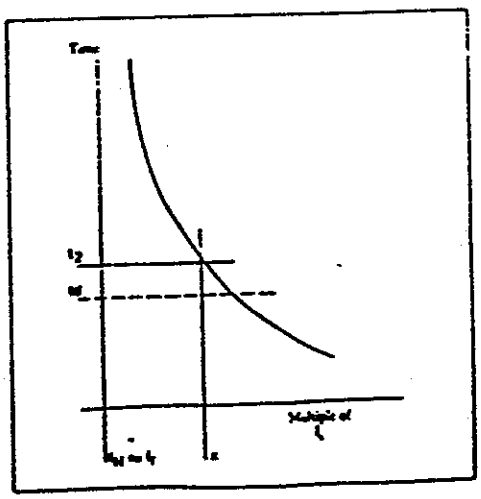
Bi-metal thermal overload relays

The relay rating will be selected according to the motor's I_s current.

However, it must allow for starting, or consecutive starts to occur without unwanted tripping. For this reason, it is necessary to check the tripping time at the I_r multiple flowing through the relay during starting.

thus

thermal overload relay tripping time t_2	>	starting time td at the I_r multiple



The thermal overload relay's tripping curve is taken into account from the cold state.

To determine the relay's tripping time t_2, calculate the I_r multiple which will flow through the overload relay.

During starting, the I_2 current has a value of :

$$I_2 = p \cdot I_N \cdot k^2 + 0{,}25\ I_N$$

and X, a multiple of I_r, can be obtained by putting $I_N = I_r$

$$X = \frac{p \cdot I_N \cdot k^2 + 0{,}25\ I_N}{I_N}$$

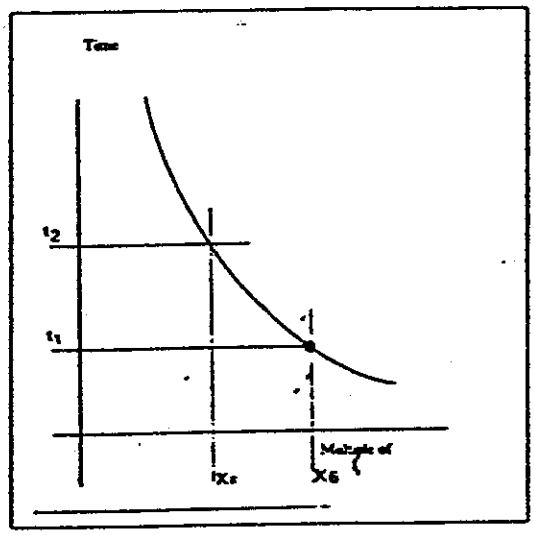
$$\boxed{X = pk^2 + 0{,}25}$$

$p : \frac{ID}{I_N}$

k : ratio of the AT < 1

X : multiple of the set current by putting $I_N = I_r$

Calculation of time t_2



If 1 point on the curve is known, for example, the time t1 at $6I_r$,
It is possible to calculate the time t_2 for a multiple other than I_r, according to the following rule

$$6^2_{I_r} \times t_1 = X^2_{I_r} \times t_2$$

thus

$$t_2 = \frac{36t_1}{(X)^2_{I_r}}$$

or $X_{I_r} = pk^2 + 0{,}25$ therefore

$$\boxed{t_2 = \frac{36t_1}{(pk^2 + 0{,}25)^2}}$$

The overload relay must permanently satisfy the relationship :

$$\frac{36t_1}{(pk^2 + 0{,}25)^2} \geq td$$

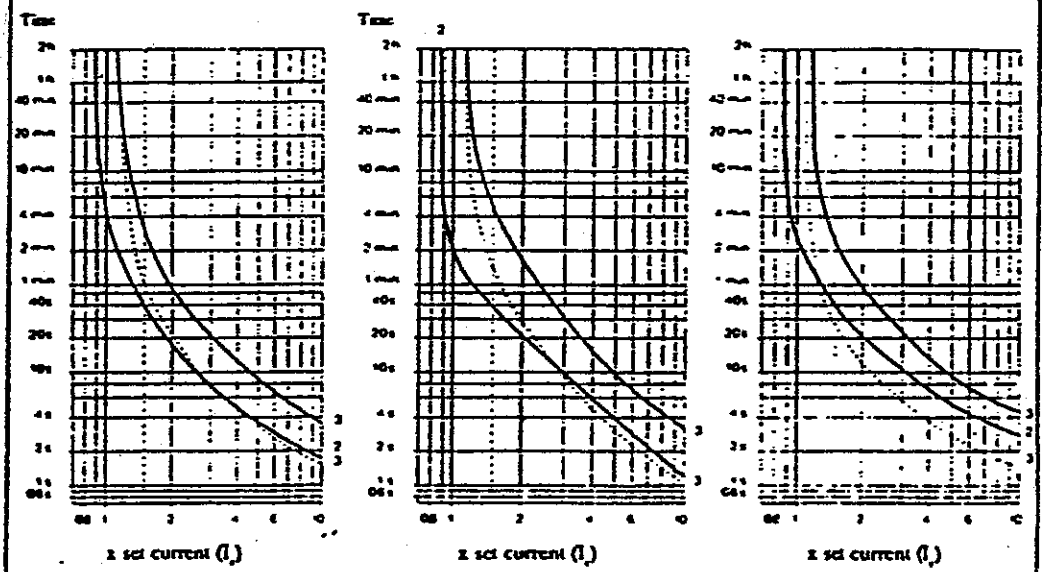
As a guide, for TELEMECANIQUE thermal overload relays

t_1 at $6I_r$ = 7s for LR1 D09 to D80
and LR1 F105 and F125

t_1 at $6I_r$ = 8s for LR1 F160 to F1000

TRIPPING CURVES

LR•-D09 to D80 LR•-F105, F125 LR•-F160 to F1000



3 ..... Balanced operation, 3 phase, from cold state
3 ..... Balanced operation, 3 phase, after long period of set current flow (hot state)
2 ..... Operation on phase failure, from cold state (except overload relay type LR3)

EXAMPLE :

Is it possible to accept two consecutive starts of 15s with a class 10 bi-metallic thermal overload relay knowing that :

$p = \frac{ID}{I_N} = 7$, $k = 0{,}65$, motor $I_N = 105$ A (55kW/380V)

ANSWER : for 105 A select an LR1 F105 thermal overload relay
for which $t_1 = 7s$

td = 2 x 15 s = 30 s and

$$t_2 = \frac{36 \times 7}{7 \times 0{,}65^2 + 0{,}25)^2} = 24 \text{ s}$$

therefore 24 s < 30 s

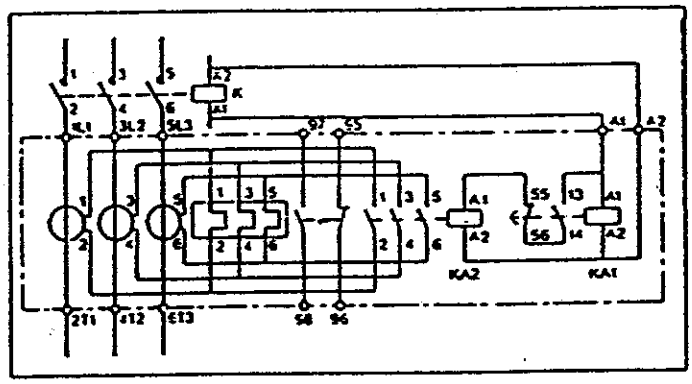
Conclusion : this thermal overload relay is not suitable.

Long starting periods

For long starting, there are several possible solutions : ·

1) Short out the overload relay during starting according to the circuit diagram below :

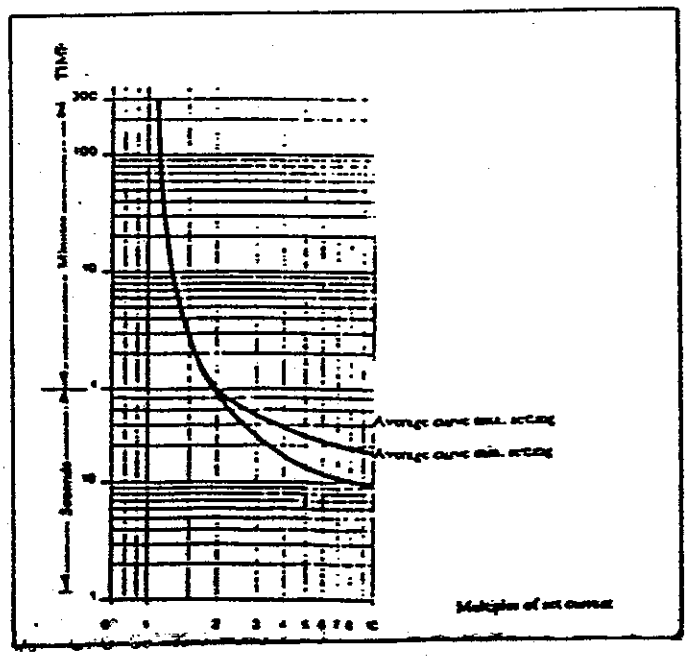
Circuit diagram for non-reversing starter



The time is adjustable from 0,1 to 30s.
To obtain a time > 30s, change the time delay relay

2) Connect the thermal overload relay to saturable magnetic circuit current transformers

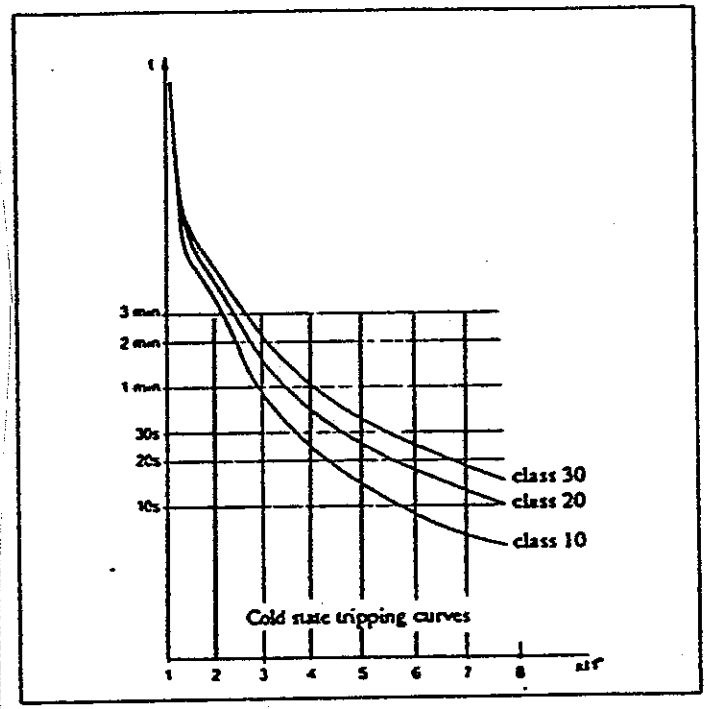
Tripping curves for LR6-F overload relays



Average curves for balanced operation. 3 phase, starting from cold state.

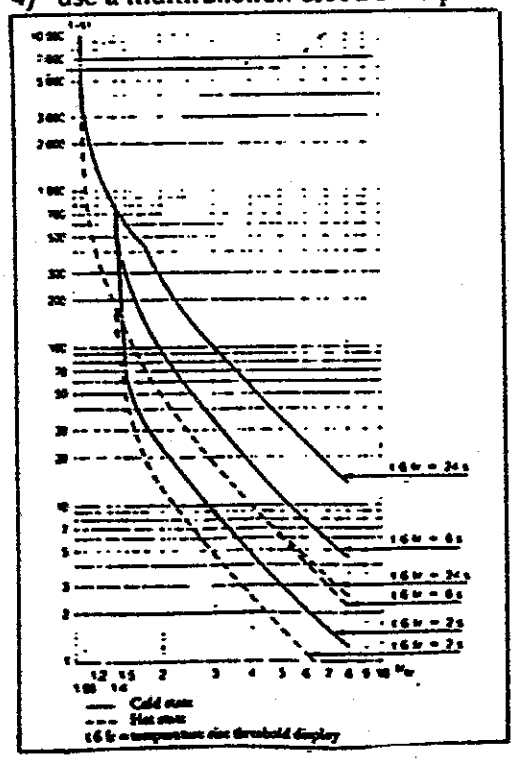
* In this case, it is preferable to consult the motor manufacturer in order to verify that the motor can accept a high slip during the starting phase.

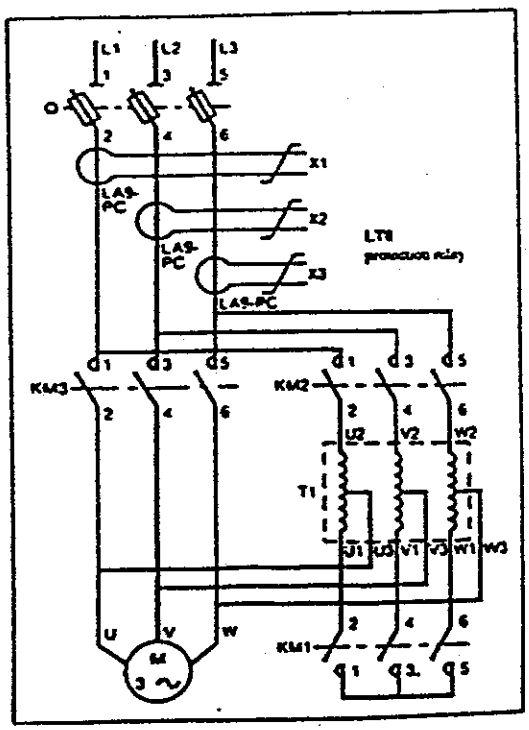
3) Use a switchable class electronic protection relay.



This amounts to the same thing as moving the tripping curve, according to the starting time, by the use of a selector.

4) use a multifunction electronic protection relay.





This product enables the adjustment of the operating class, by the use of a potentiometer.

Its use, independent of the aforementioned function, can be justified by the higher level of protection it gives the installation, generally of a high cost, and requiring operation continuity to be ensured.

Example of an AT starter calculation

For a 280 kW - 380 V - 50 Hz compressor motor.

- the I_N motor current is 517 A
- the transformation ratio is k = 0,68
- the ratio $p = \frac{ID}{I_N} = 6,5$
- the number of starts/hour is 3, of which two are consecutive and td = 30 s for each
- ambient air temperature ≤ 40 C°
- I_2 current calculation (contactor KM2)

$$I_2 = pI_Nk^2 + 0,25\ I_N$$

$$= 6,5 \times 517 \times 0,68^2 + 0,25 \times 517$$

$$I_2 = 1683\ A$$

- I_1 current calculation (contactor KM1)

$$I_2 = pI_Nk(1 - k) - 0,25\ I_N$$

$$= 6,5 \times 517 \times 0,68\ (1 - 0,68) - 0,25 \times 517$$

$$I_1 = 602\ A$$

- Transient current calculation on closing of KM2

$$\hat{I} = \frac{2,5\ PM}{U} = \frac{2,5 \times 280.000}{380} = 1842\ \hat{A}$$

- Transient current calculation on closing of KM3

This value can only be estimated.

In this case, for any air gap, use

$\hat{I} = 6\sqrt{2}\ I_N$ where :

$\hat{I} = 6 \times \sqrt{2} \times 517 = 4387\ \hat{A}$

Selection of contactor KM2

The IeAC1 equivalent current is calculated by putting :

- starting time 2td = 30 x 2 = 60 s
- cycle time : $T = \frac{3600}{2} = 1800$ s
- Then develop, by the iterative method, the function

$IeAC1 = I \times Q$

For 2td = 60 s retain for the first approach the average Q value, 0,35 (page 11, first part), thus

$IeAC1 = 1683 \times 0{,}35 = 589$ A

For this value, the catalogue suggests an

LC1-FK (IeAC1 = 700 A)

to be more precise, for the LC1-FK, the factor is

Q = 0,29 thus

$IeAC1 = 1683 \times 0{,}29 = 488$ A

For this value, the catalogue suggests an

LC1-FJ (IeAC1 = 500 A)

with still more precision, for the LC1-FJ, the factor is

Q = 0,29 thus

$IeAC1 = 1683 \times 0{,}29 = 488$ A

CONCLUSION : this contactor rating is correct.

Now check the second condition concerning the making capacity, where

MC catalogue = 4000 A thus

$\hat{I} = 4000\sqrt{2} = 5686$ Â and

5686 Â > 1842 Â

The choice of the LC1-FJ is therefore confirmed.

Selection of contactor KM1

Proceed in the same way as for the previous calculation

- where 2td = 30 x 2 = 60 s
- cycle time : $T = \frac{3600}{2} = 1800$ s
- first approach with Q = 0,35 thus

  IeAC1 = 602 x 0,35 = 210 A

For this value, the catalogue suggests an

LC1-FG (IeAC1 = 270 A)

to be more precise, for the LC1-FG, the coefficient is

Q = 0,37 thus

IeAC1 = 602 x 0,37 = 222 A

therefore the contactor rating is correct

Check the condition concerning the making capacity, where

MC catalogue = 1800 $\sqrt{2}$ = 2545 Â, and

2545 Â > 1842 Â

The choice of the LC1-FG is therefore confirmed.

Selection of contactor KM3

Find, in the catalogue, the contactor corresponding to the motor IeAC3.

IeAC3 = 517 A

The LC1-FL contactor will be retained, whose catalogue values are :

IeAC3 = 630 A
MC = 6300 A thus $\hat{I}$ = 6300 $\sqrt{2}$ = 8909 Â.

The choice is correct, since

630 A > 517 A
8909 A > 4387

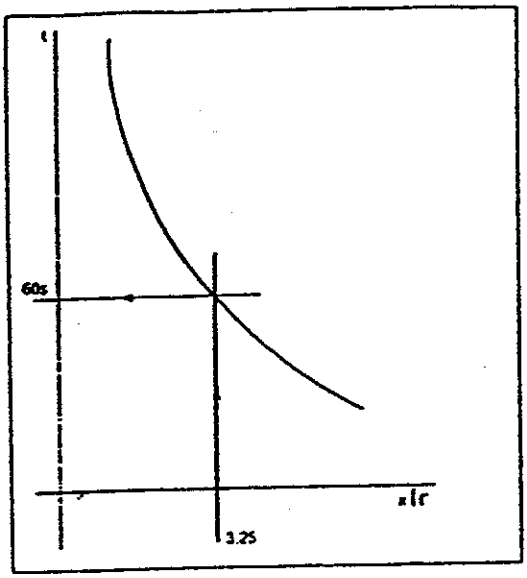
Choice of overload protection

- Calculation of I_r multiple on starting

  $x\ I_r = pk^2 + 0,25$

$= 6,5 \times 0,68^2 + 0,25$

$xI_r = 3,25$



At this multiple, the overload relay tripping curve must go through the time

$2td > 2 \times 30$ s

- A class 10 bi-metallic overload relay is not suitable, in fact it does not satisfy the relationship :

$$\frac{36t_1}{(pk^2 + 0,25)^2} > 2td$$

by putting $t_1 = 8$ s this becomes :

$$\frac{36 \times 8}{(6,5 \times 0,68^2 + 0,25)^2} = 27 \text{ s}$$

and $27 \text{ s} < 60 \text{ s}$

- a bi-metallic overload relay on saturable CTs is not suitable (see curve page 4).

Possible solutions

- by-pass the bi-metallic relay during starting
- use a switchable class electronic protection relay.

Where this is the case, class 20 is suitable

in effect

$$\frac{36 \times 20}{(6,5 \times 0,68^2 + 0,25)^2} = 68 \text{ s}$$

therefore $68 \text{ s} > 60 \text{ s}$

- use an adjustable class electronic protection relay.

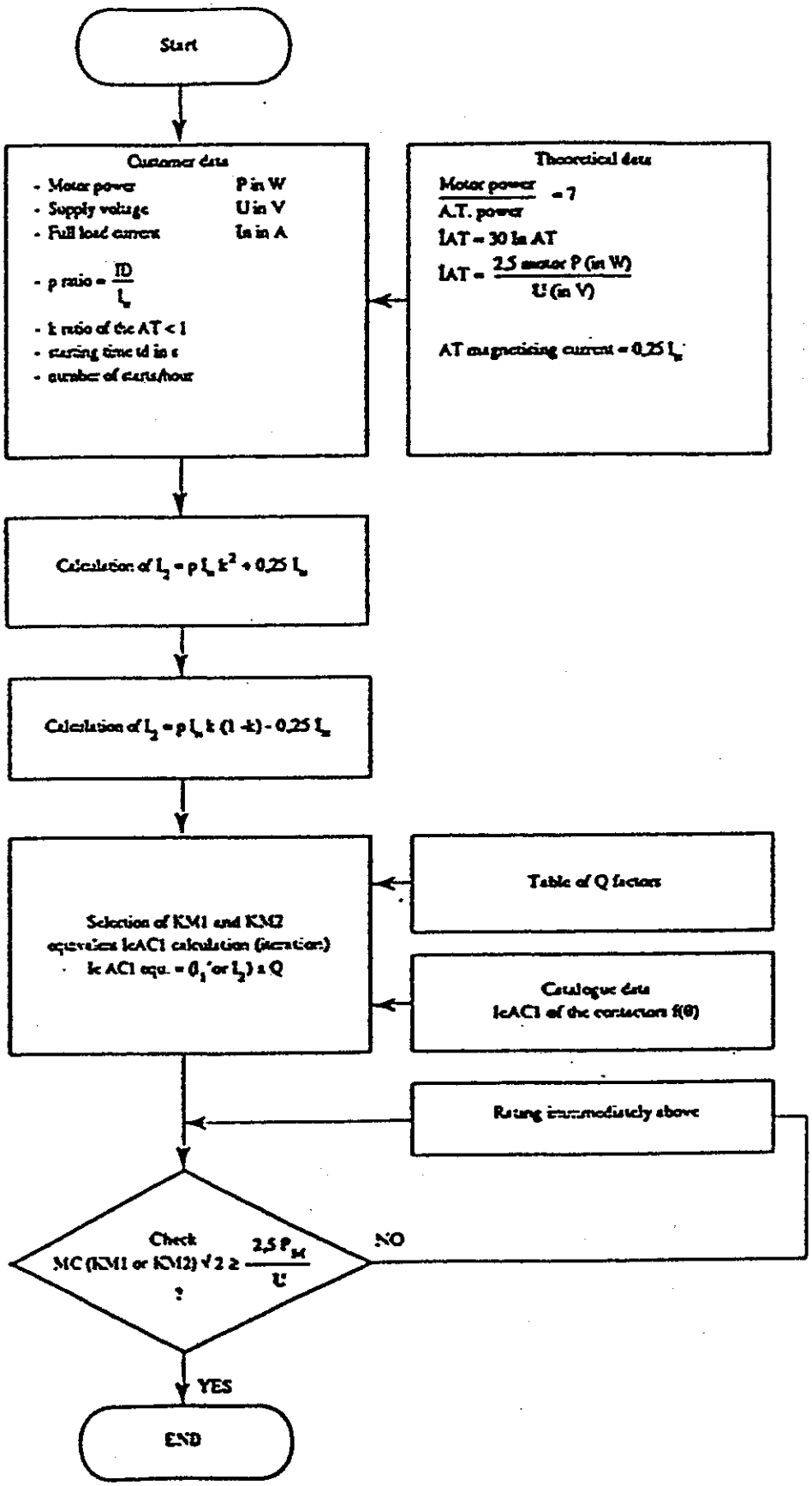
Choice of protection against short-circuits

- fit three 630 A type aM fuses

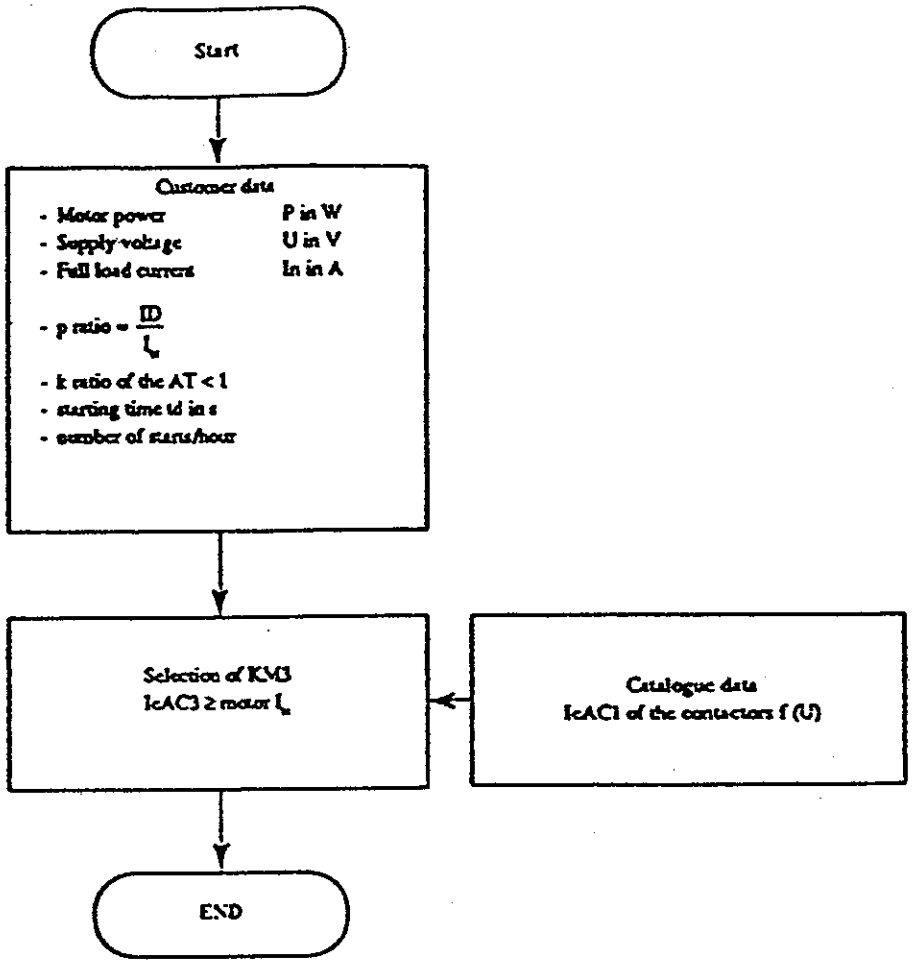
Electrical durability

- bearing in mind the low number of starts/hour, there is no problem.

Flow diagram
KM1-KM2



Flow diagram
KM3



Protection flow diagram

