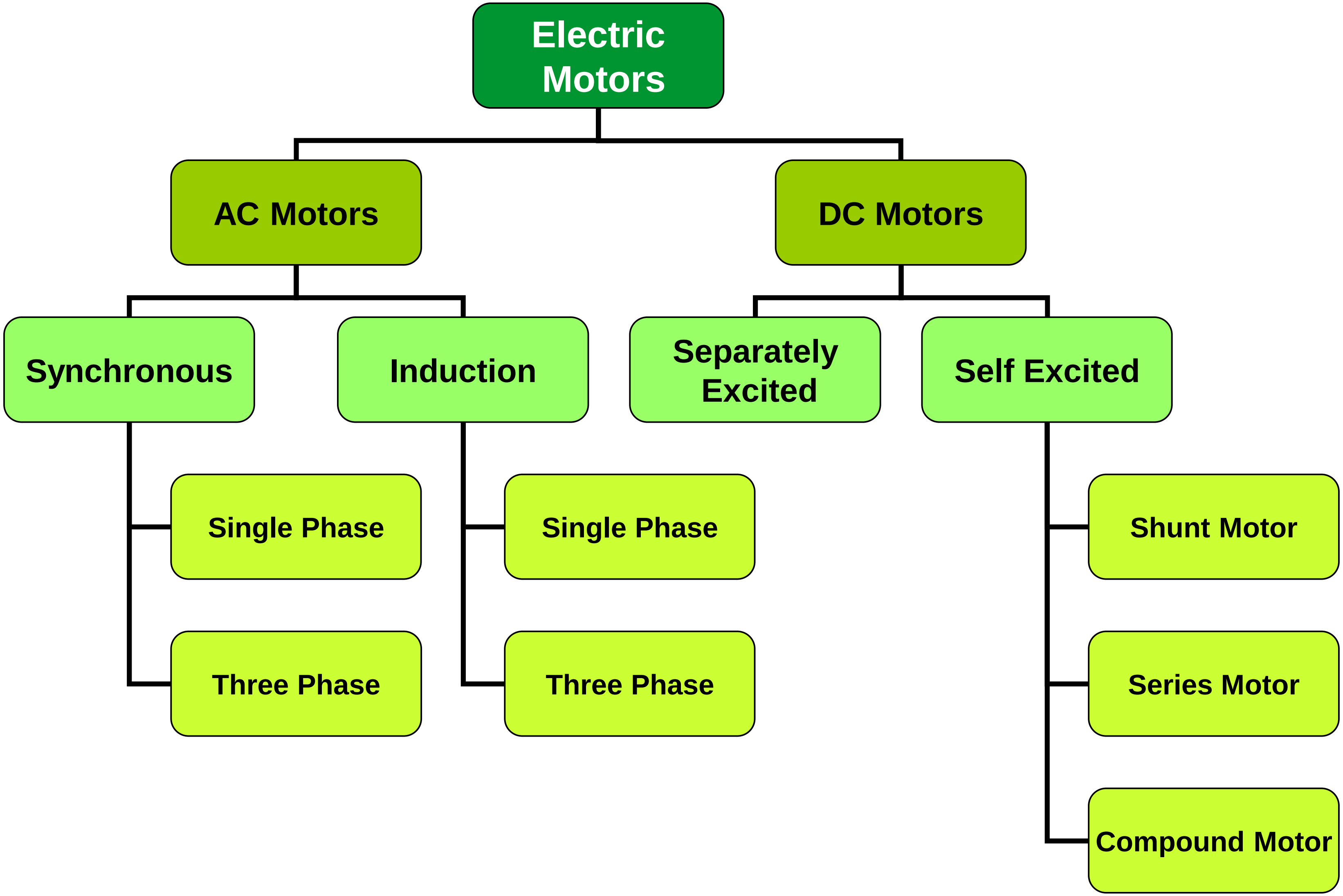
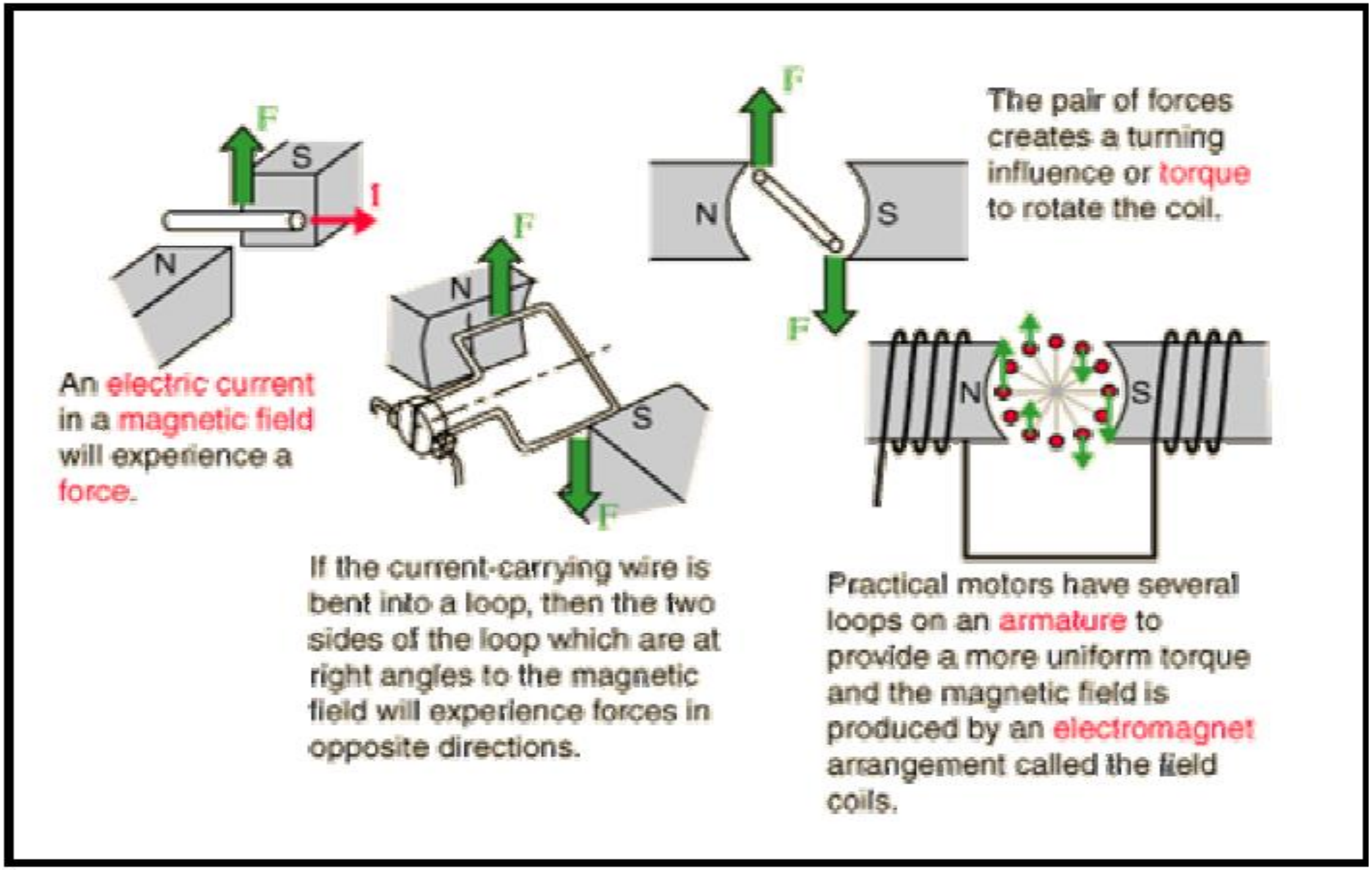
LV Motor Starting & Protection

Schneider Electric

Motor Types


Electric Motors
AC Motors
DC Motors
Synchronous
Induction
Separately Excited
Self Excited
Single Phase
Three Phase
Single Phase
Three Phase
Shunt Motor
Series Motor
Compound Motor

Motoring Action



Basic Principle of how Electric Motors Work

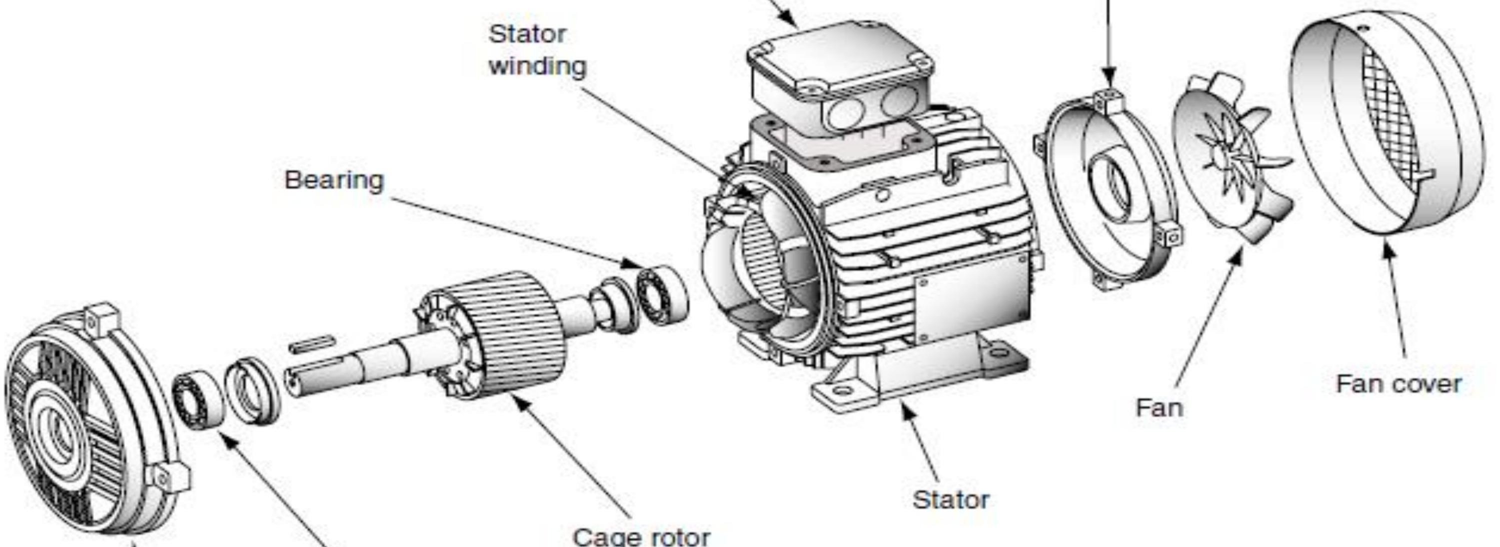
Operating Principle & Torque-Speed Characteristic

Construction Features of 3-ph IM

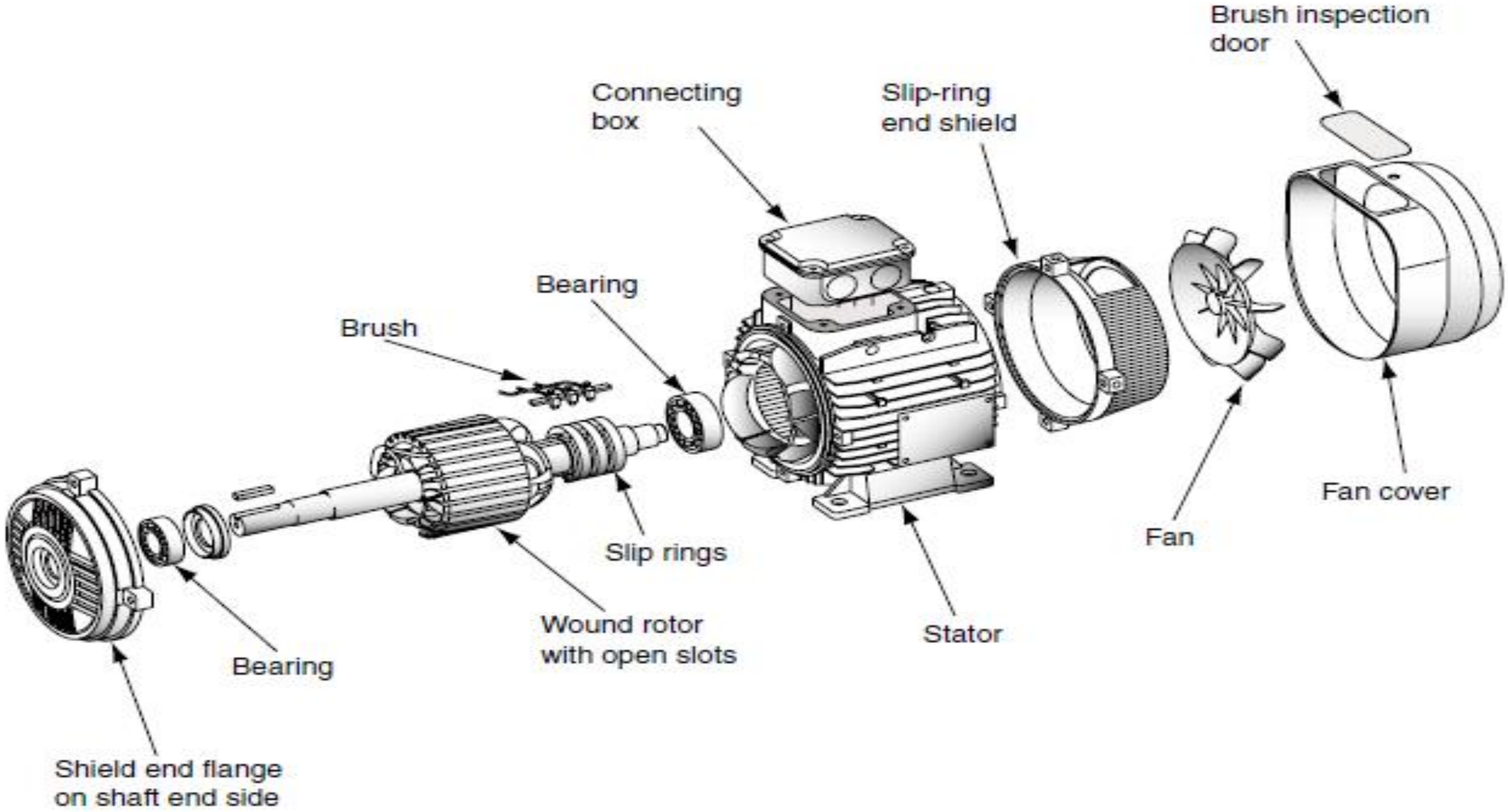
- 3-ph induction motor consists of two parts: the stator and the rotor.
- 3-ph induction motor classified according to the rotor type:
  - Slip ring (wound rotor)
  - Squirrel cage (bar windings)

Squirrel Cage Motor

- Used in the majority of industrial applications
- Simple, economical & rugged motor



Slip Ring Motor



Motor Nameplate

- It gives among others, information about the following:

- ❑ **Motor rating**
- ❑ **Motor supply details**
- ❑ **Motor connection details**
- ❑ **Motor frame type and size**
- ❑ **Motor rpm**
- ❑ **Permissible temperature rise**
- ❑ **Motor duty**
- ❑ **Enclosure type**
- ❑ **Number of poles**

Motor Insulation

- The insulation utilized should withstand the voltage fluctuations of the motor under varying operating conditions.

- Depending on the load and its surrounding conditions, there could be a rise in the temperature of the motor. The insulation should withstand such temperature rises also.

- The main characteristics of insulating materials used in electrical machines are:

✓ **Dielectric strength**
✓ **Thermal strength.**

Motor Insulation

- The insulating material used for the electrical machines are classified according to the standards as follows,

- **Class A:**

Cotton, silk, paper, and similar organic materials, impregnated or immersed in oil and enamel applied wires (Tmax = 105 C)

- **Class B:**

Mica, asbestos, glass fiber, and similar inorganic materials (Tmax = 130 C)

- **Class E:**

An intermediate class between A and B

- **Class F:**

The same as B but with silicone is added (Tmax = 155 C)

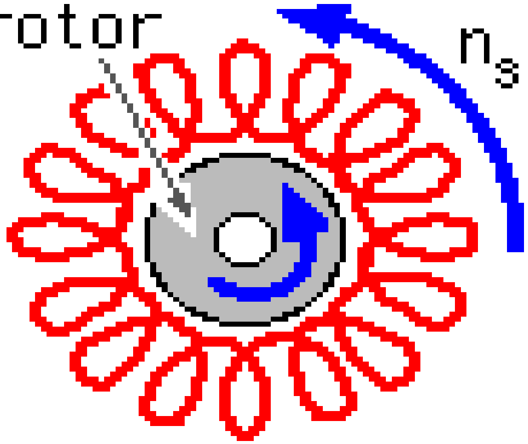
- **Class H:**

The same as F but the insulator is reinforced (Tmax = 180 C)

Slip

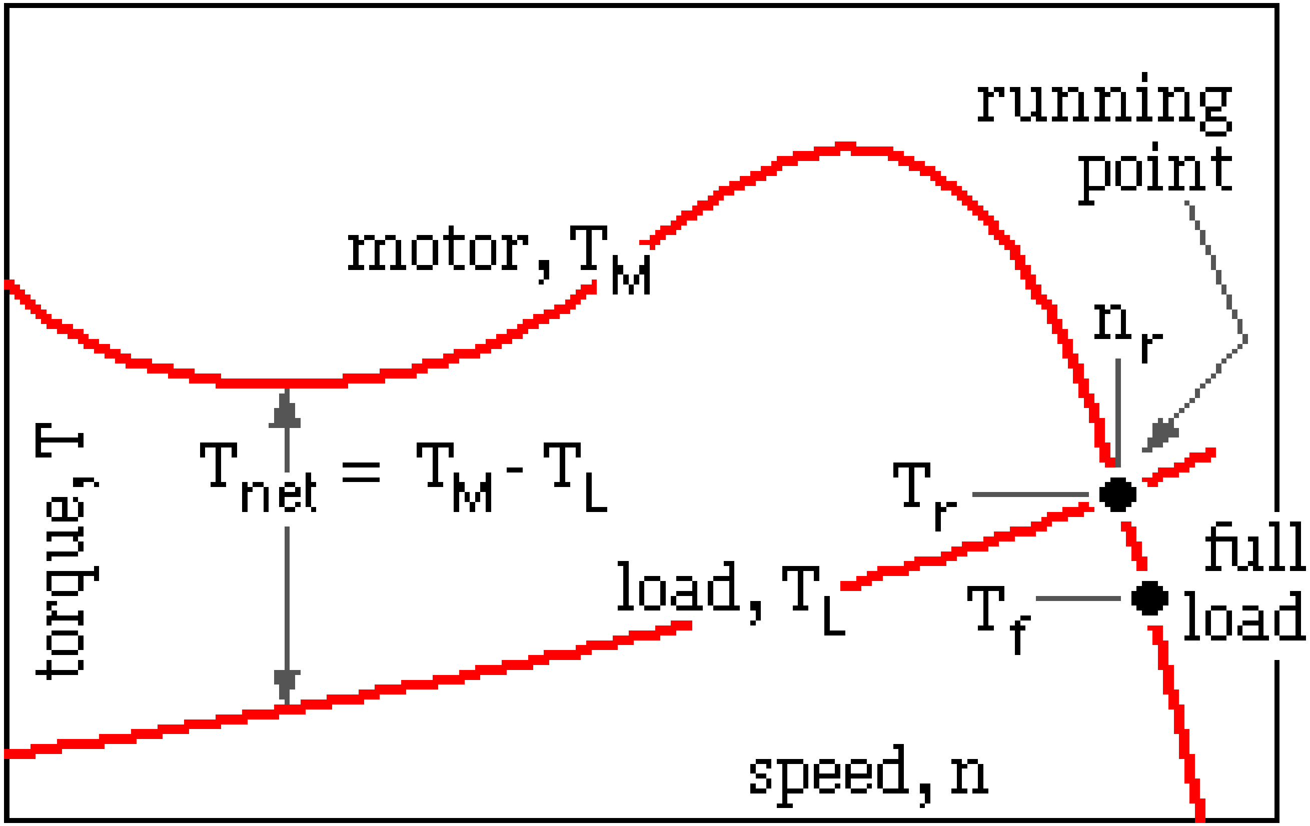
- If there is no slip the induced emf in the rotor and the developed torque equal zero
- Ns : Stator rotating field speed,
  Nr : Rotor winding speed relative to stator winding,
  (Ns-Nr) : Speed of rotor winding relative to stator flux, and

Slip (s) = (Ns-Nr)/Ns



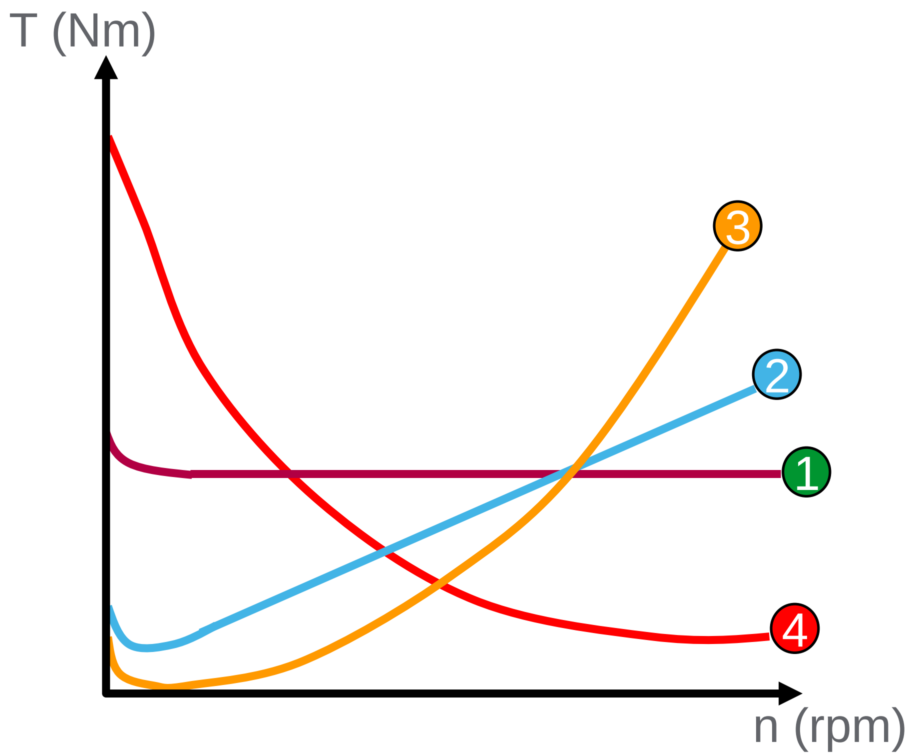
Torque Speed C/Cs

- By analysis, it was found that the speed torque C/Cs is as shown



Load Types

According to the torque C/Cs the loads are classified as follows



① **Constant torque 90% of applications**

Hoisting

Conveyor belts

②**Linear torque**

Volumetric pumps

③ **Parabolic torque**

Fans

④ **Hyperbolic torque**

Winders unwinders

Machine tools

Factors influence motor efficiency:

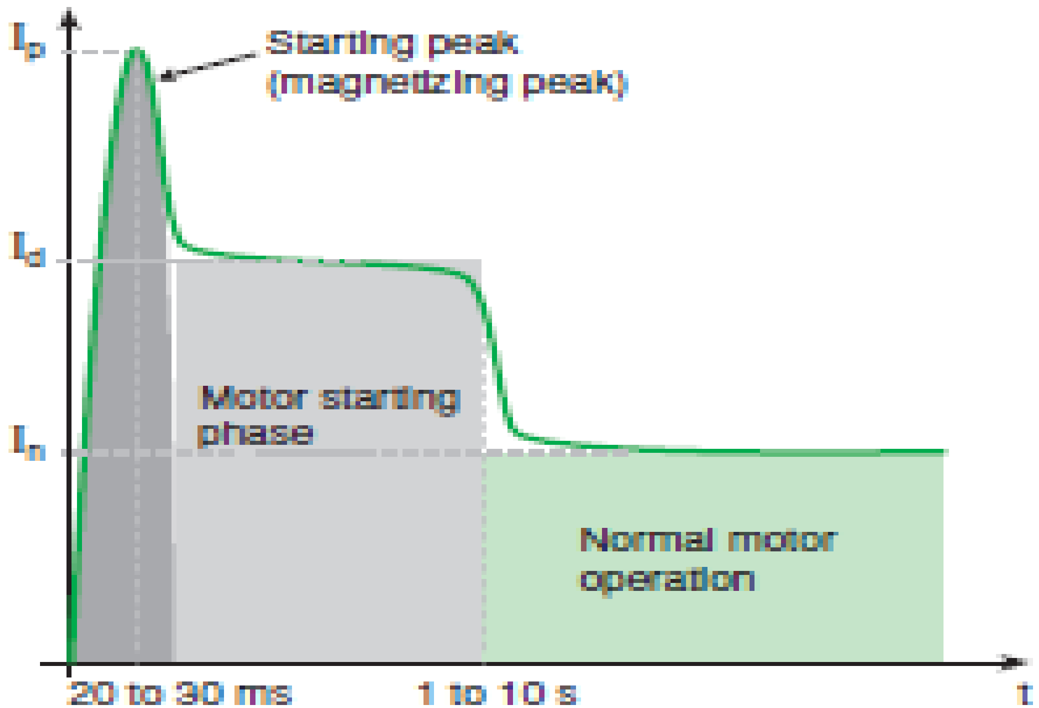
- **Age:** New motors are more efficient.
- **Capacity:** As with most equipment, motor efficiency increases with the rated capacity.
- **Speed:** Higher speed motors are usually more efficient.
- **Type:** For example, squirrel cage motors are normally more efficient than slip-ring motors.
- **Temperature:** Totally-enclosed fan-cooled (TEFC) motors are more efficient than screen protected drip-proof (SPDP) motors.
- **Rewinding** of motors can result in reduced efficiency.
- **Load** of the motor.

Efficiency Improvement Areas used in Energy Efficient Motors

Power Loss Area	Efficiency Improvement
1. Iron	▪ Use of a thinner gauge because lower loss core steel reduces eddy current losses. ▪ Longer core adds more steel to the design, which reduces losses due to lower operating flux densities.
2. Stator I2R	▪ Use of more copper and larger conductors increases cross sectional area of stator windings. This lowers the resistance (R) of the windings and reduces losses due to current flow (I)
3 Rotor I2R	▪ Use of a larger rotor conductor bars increases the cross section, thereby lowering the conductor resistance (R) and losses due to current flow (I)
4 Friction & Winding	▪ Use of a low loss fan design reduces losses due to air movement
5. Stray Load Loss	▪ Use of optimized design and strict quality control procedures minimizes stray load losses

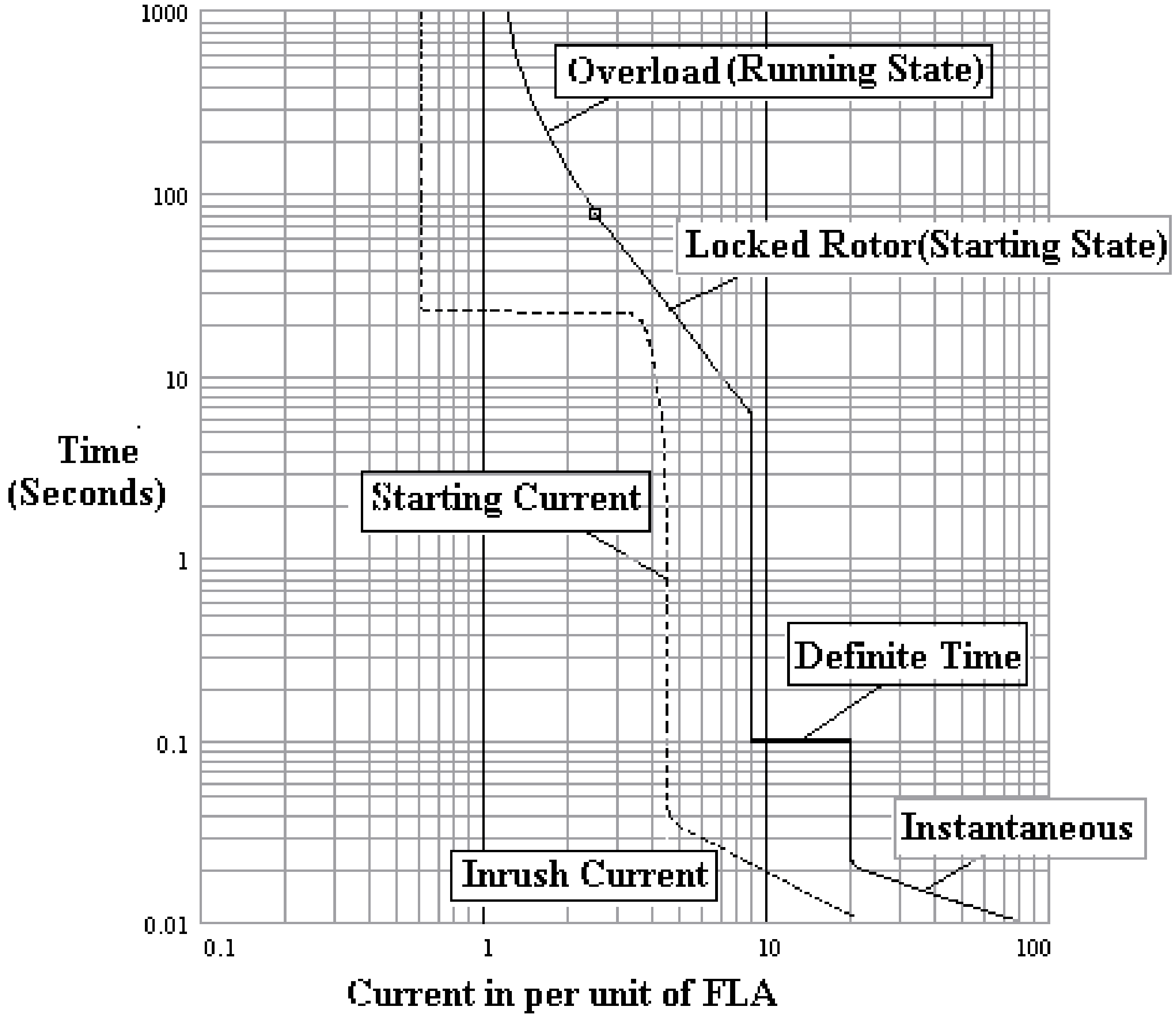
Motor Starting

Induction Motor Starting



I_p = 10 to 13 I_n: Magnetizing current
I_d = 4 to 8 I_n: Starting current
I_n: Nominal rms current

Induction Motor Starting



Faults (Causes & Effects)

Causes of faults and their effects

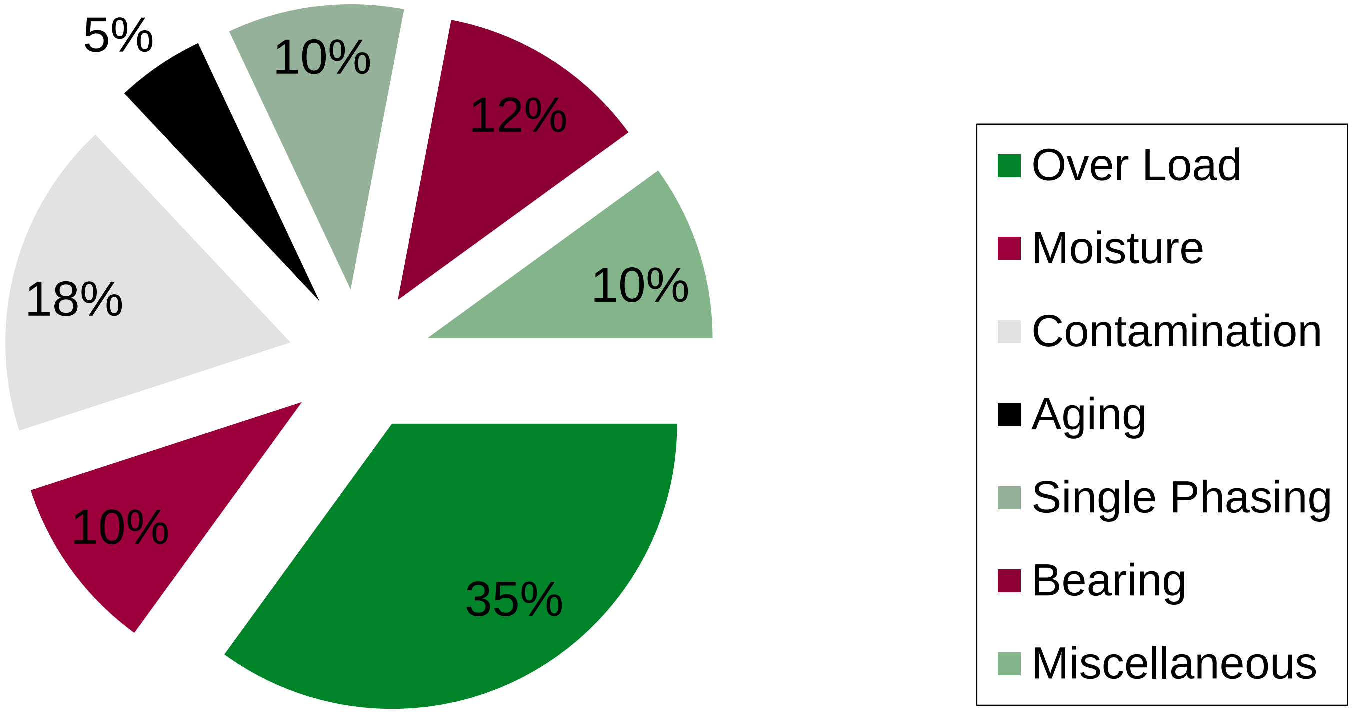
- Motor Faults
  - Internal
  - External

- Internal Faults
  - phase to ground short circuit
  - phase to phase short circuit,
  - Internal winding short circuit,
  - Overheating of windings,
  - broken bar in squirrel cage motors,

External Faults

- **Power Supply**
  - Power Failure
  - Inverted or unbalanced phases
  - Voltage surge
- **Operating conditions**
  - Overload states
  - Excessive no. of starting and braking
  - Abnormal starting state
- **Installation Conditions**
  - misalignment
  - unbalance
  - Stress on shaft

Statistical Data about Motor Faults



Measurements used for motors

- The following are the measurements used for a motor:

- Temperature: thermocouple/resistance element/thermistors measure temperatures of windings, bearing, etc.
- Voltage and current: using portable voltmeter, recording voltmeter, ammeters- clamp type, CRO, etc.
- Insulation resistance: Meggers
- Winding resistance: Kelvin bridge, wheatstone bridge, resistance meters.
- Vibrations: Vibration metering, monitoring, and analyzing equipment
- Speed: Stroposcope, tachometer, etc.
- Dielectric loss angle: Tan-delta measurement

Motor Protection and Coordination

MOTOR PROTECTION
Types of faults

Faults due to the power supply

Faults due to the load

Motor internal faults

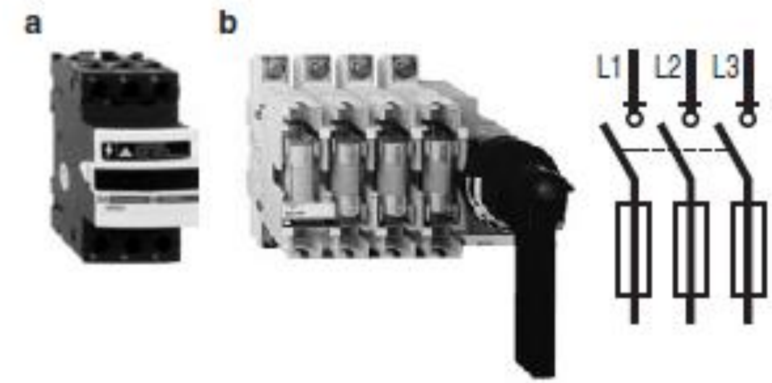
Associated functions to Motor Switching

Function	Description
Low voltage distribution	
Isolation	**Isolate equipment from electrical supply**
Disconnection	**Interrupt current through equipment**
Short circuit protection	**Protect against human and material damages**
Overload protection	**Protect motors against overload current effects**
Switching	**ON / OFF loads**

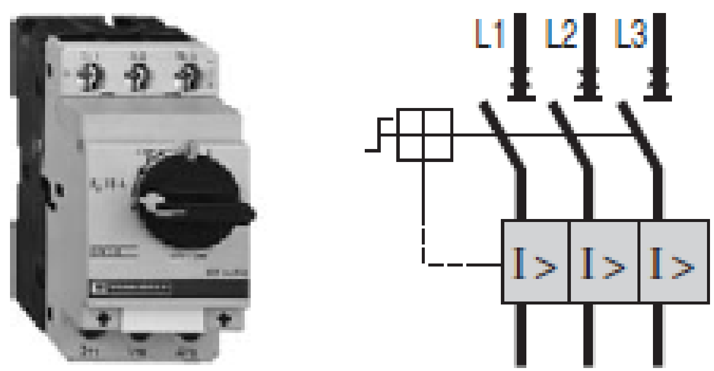
MOTOR PROTECTION FUNCTIONS

1. SHORT CIRCUIT PROTECTION.

A. FUSES



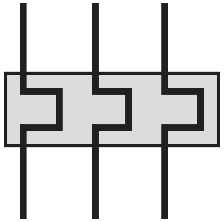
B. CIRCUIT BREAKERS.



MOTOR PROTECTION FUNCTIONS

2. OVERLOAD PROTECTION.

A. OVERLOAD RELAYS (thermal or electronic)



B. PTC THERMAL PROBES

The load break switch / isolator

- This device has disconnection and isolation capability
- Can be used safely « on load »
- It does not include any protection mechanism
- May be used as an emergency stop button (with yellow cover and red handle)

The Thermal Relay

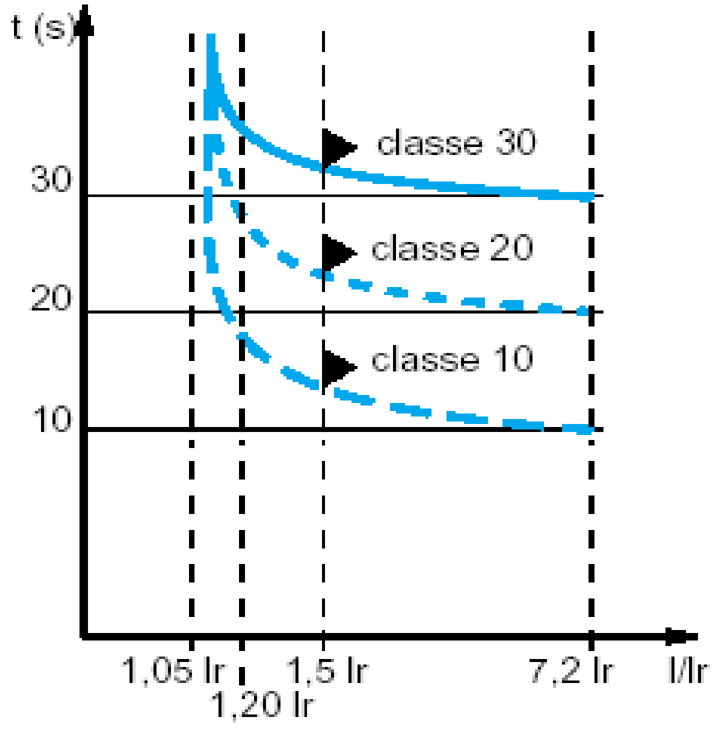
LRD Relay

- Overload is the most common fault on machines
- Overload creates an increase in current drawn by the load and leads to dangerous overheating of the load.
- Overheating can affect the isolating materials and thus the lifetime of the motor
- The relay is made of 3 bimetal elements, each being surrounded by a heating coil carrying its phase current.
- As the motor draws current, the bimetal will bend and the amount of bending is linked to the level of current

Tripping class

Definition

The class define the tripping time to 7.2 I_r ; the selection is depending to the nature of the application.

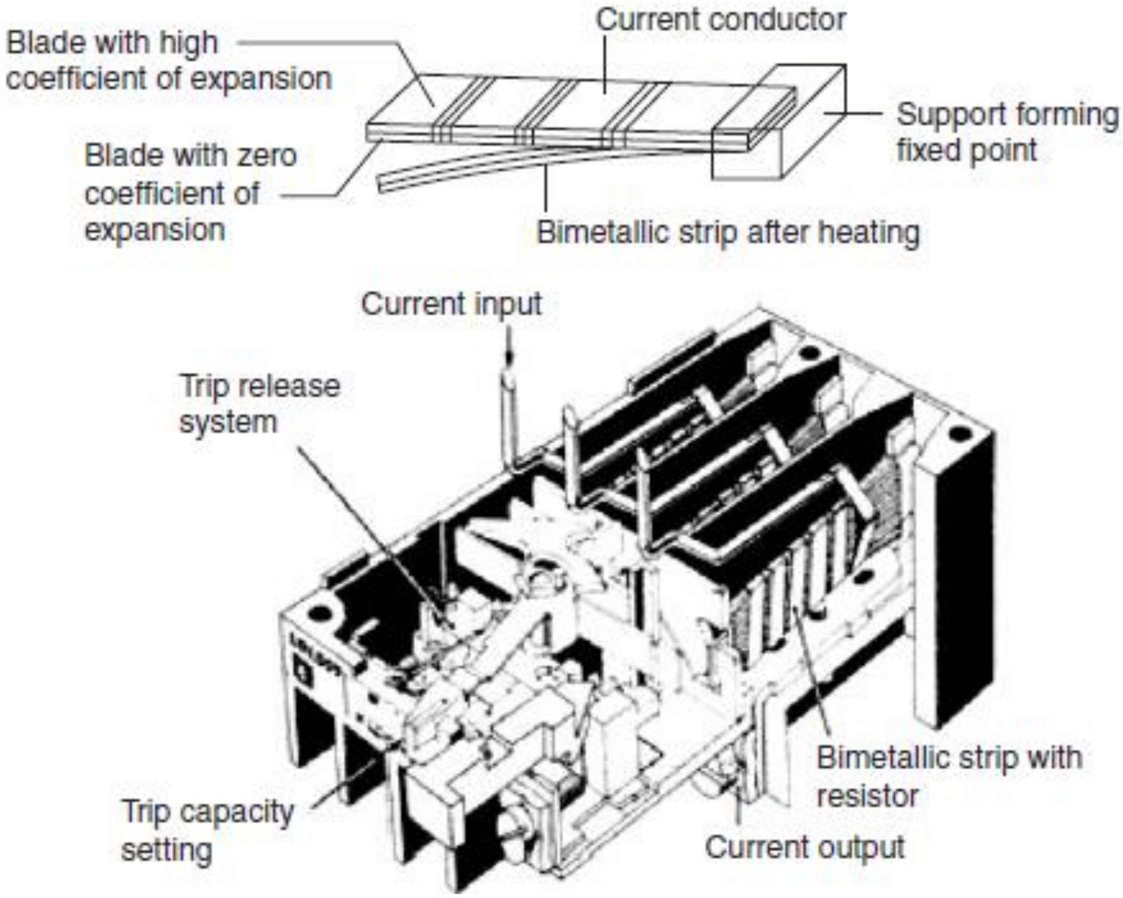


Class 10 **$4 < T_p <= 10s$**

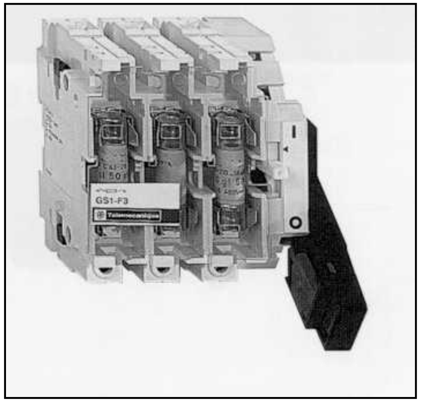
Class 20 **$6 < T_p <= 20s$**

Class 30 **$9 < T_p <= 30s$**

The Thermal Relay



The Manual Fused Switch Isolator



GS1

- These devices can be operated on load
- Include fuses to provide short circuit protection
- The operation is often made through side handle

The Magnetic Circuit Breaker

GV2-L

- Device which provides short-circuit protection. It detects and break high levels of short circuit currents up to the limit of their breaking capacity.

- Has disconnection capability

- Reset after fault can be done manually by operating the rotary switch, or remotely using optional module

- For relatively low fault currents, the operation of a circuit breaker is faster than that of fuses

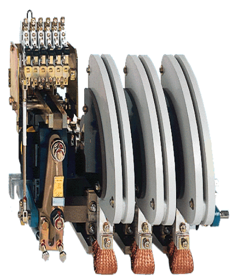
The Magnetic Thermal Circuit Breaker

GV2-ME

- This circuit breaker includes both magnetic protection against short circuits, and thermal protection (motor overload)
- Since it includes all types of protection and has disconnection capability, it can be used as a motor starter for simple machines.
- Optional blocks can be added to enable remote reset and control of the circuit breaker.

The Contactor

LC1-D contactor



Bar contactor

- Makes and breaks current on loads – Switching capacity
- Operated remotely using an electromagnet and a separate control circuit
- When the coil of the electromagnet is energized, the mobile part of the contactor moves and current can flow from the supply network to the load.
- Auxiliary contacts are included and moving simultaneously with the mobile part of the contactor

The Combined Motor Starter

Integral

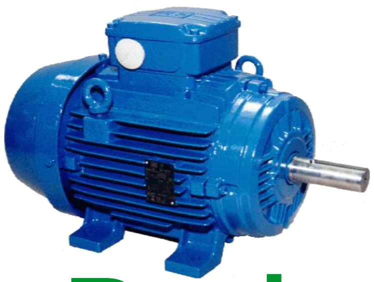
- In 1983, Telemecanique introduced the first device capable of disconnection, switching and thermal-magnetic protection : the INTEGRAL

TeSys U

- This type of product offers all motor starting functions in one product

- Provides total coordination : no contacts welding after short-circuit, reduced maintenance operation

- TeSys U starter offers embedded communication capability with field buses and modularity .

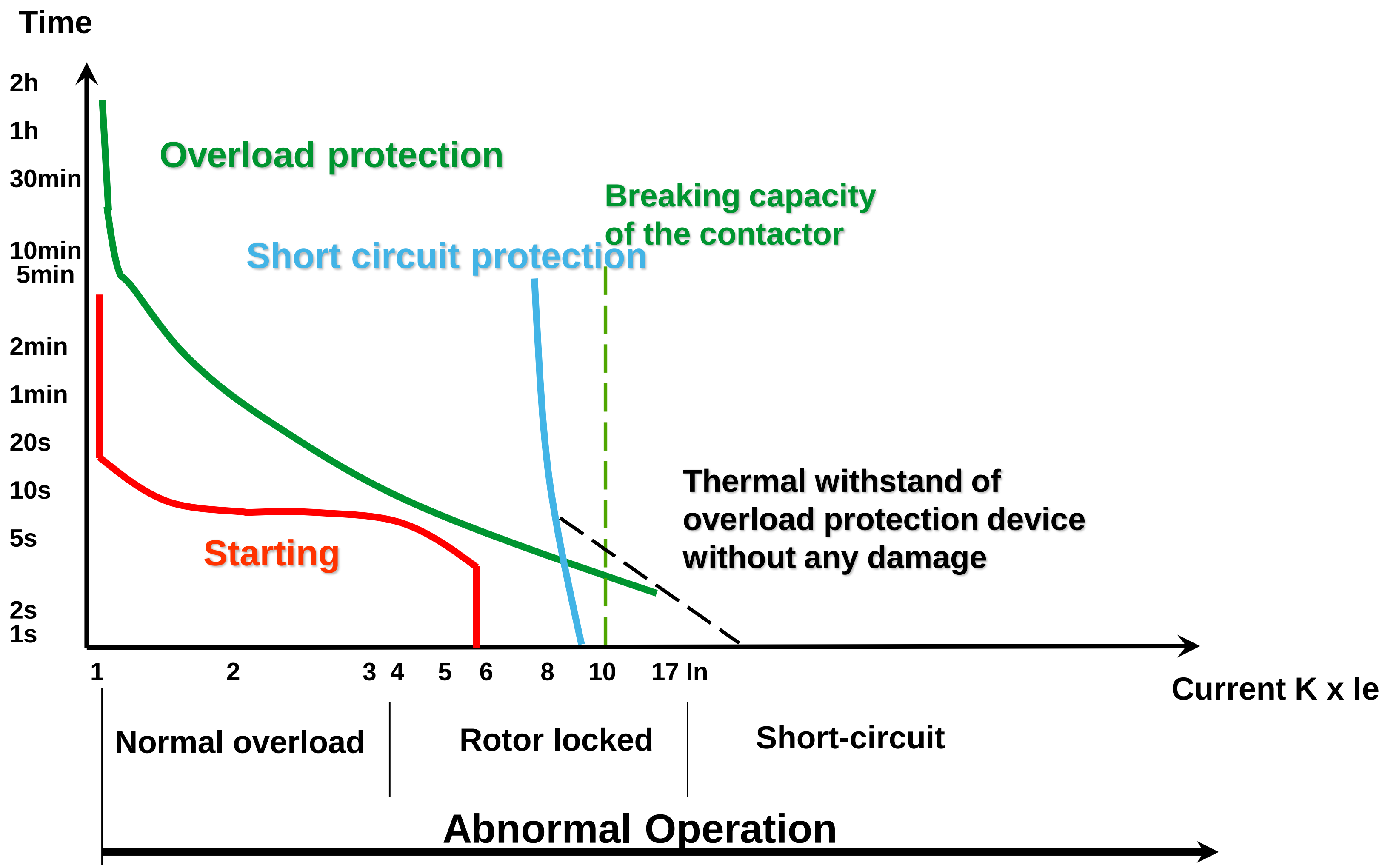


Motor Starter
Basic Coordination Theory

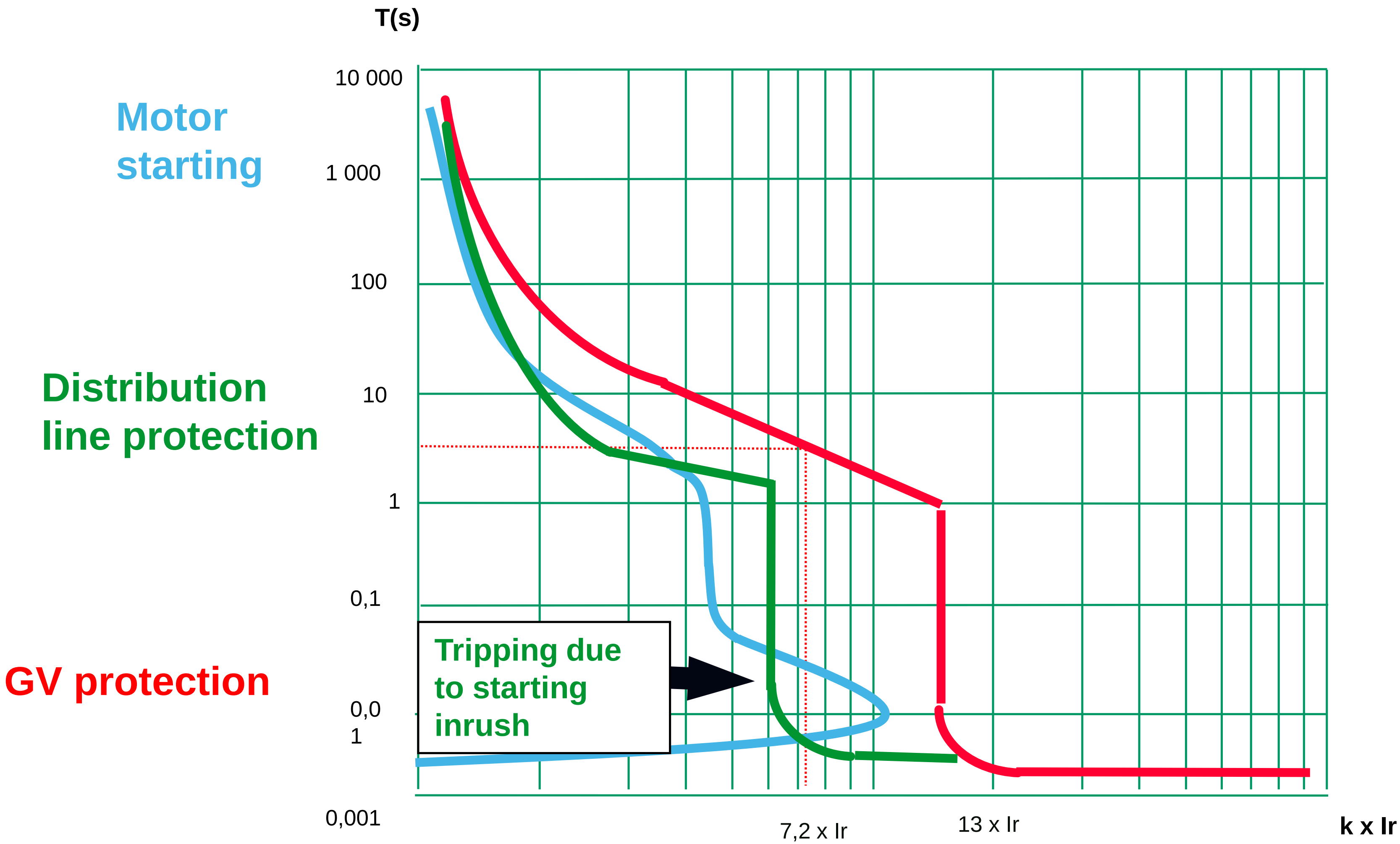
IT curves of protective devices

Contactors and motor starters

Coordination with short-circuit protection devices



Motor circuit breaker & Distribution protection

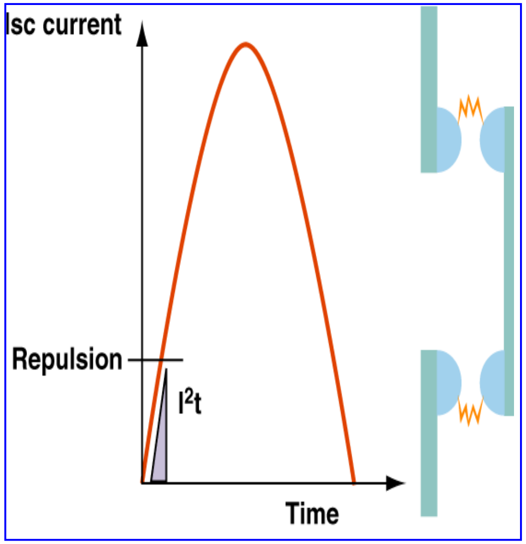


Effects of a short-circuit on the contactors

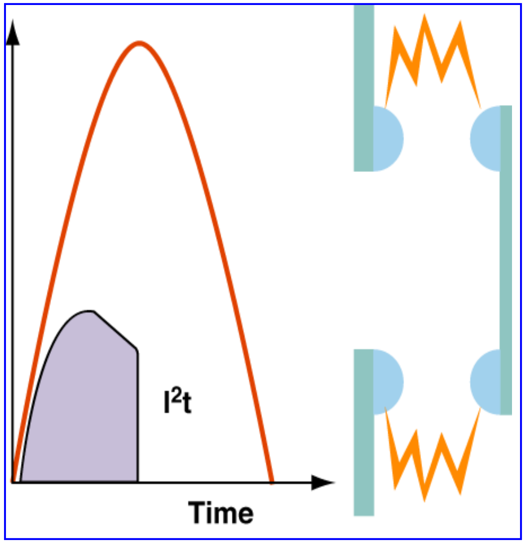
- Electrodynamics effects of peak current Imax:
  - repulsion of contacts
  - propagation of electrical arcs
  - damage to isolation equipment and deformation of parts

- Thermal effects I^2t:
  - fusion of contacts
  - generation of electrical arcs
  - heat damage to isolation equipment

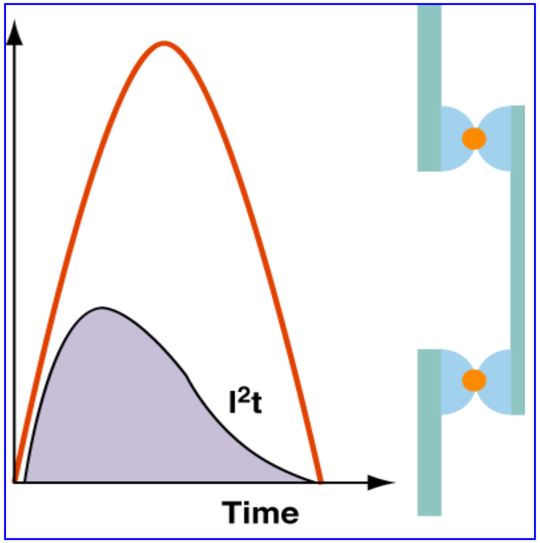
Behavior of contactor under the effect of <u>non limited</u> short-circuit currents



Repulsion of the contacts, due to the energy delivered by the short-circuit

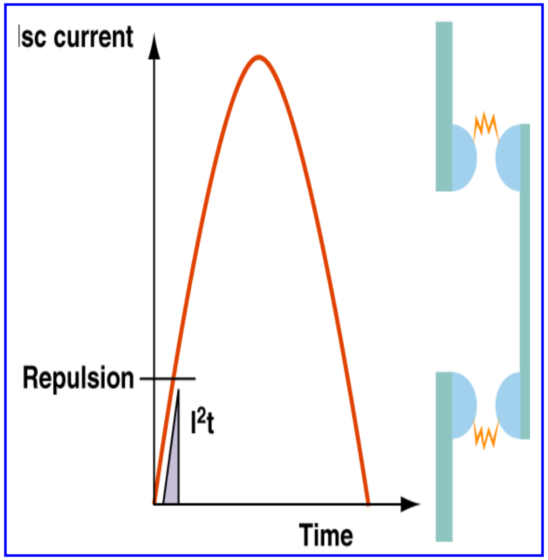


The energy due to the short-circuit becomes very high, the arc becomes important

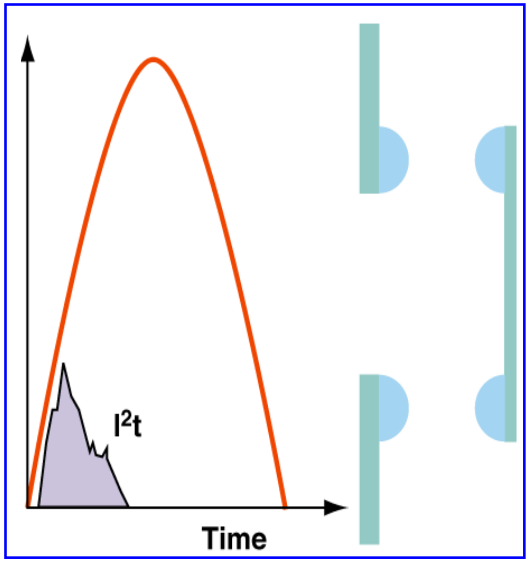


The silver contacts becomes liquid and weld

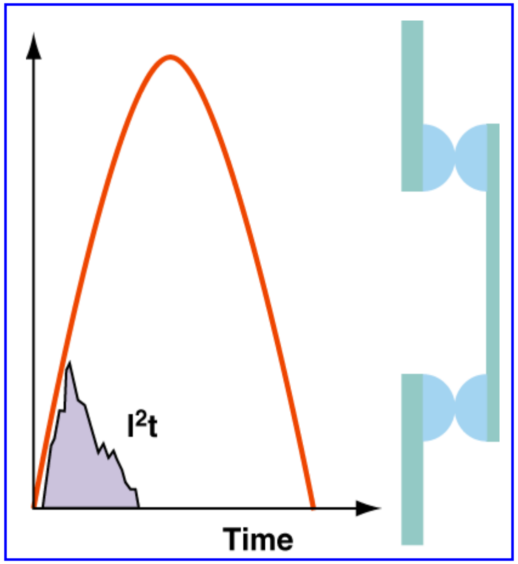
Behavior of contactor under the effect of <u>limited</u> short-circuit currents



Start of repulsion of contacts under the effect of the short-circuit



The energy from the short-circuit is limited and repulsion is stopped



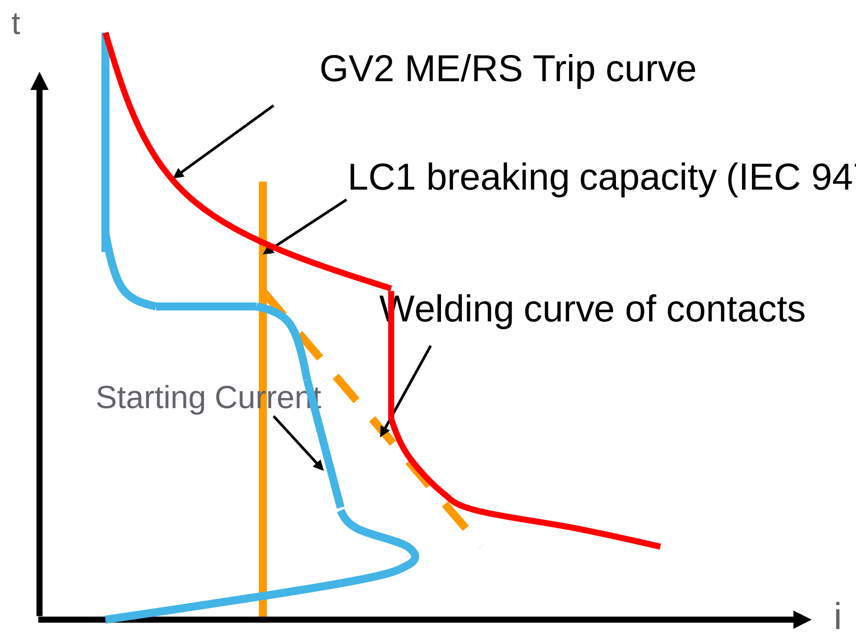
The contacts remain operational

Coordination type: NO Coordination

GV2ME / RS → **Isolation**
I>> Protection
Thermal Overload Protection

+

LC1 → **Command**

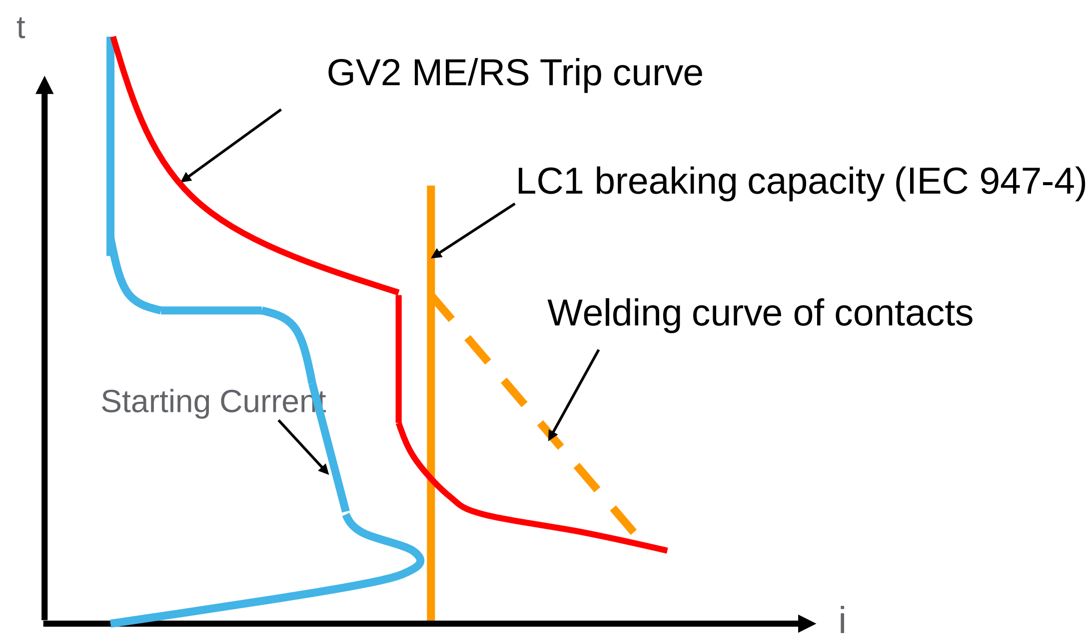


Coordination type: Coordination Type 1

GV2ME / RS → Isolation
I>> Protection
Thermal Overload Protection

+

LC1 → Command

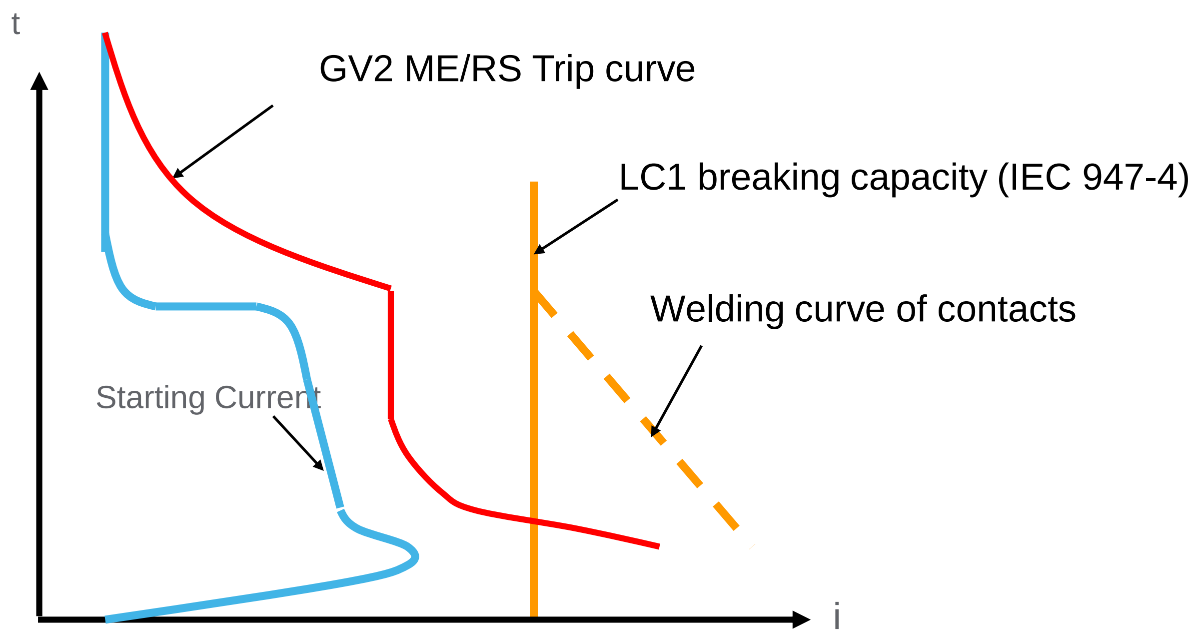


Coordination type: Coordination Type 2

GV2ME / RS → Isolation
I>> Protection
Thermal Overload Protection

+

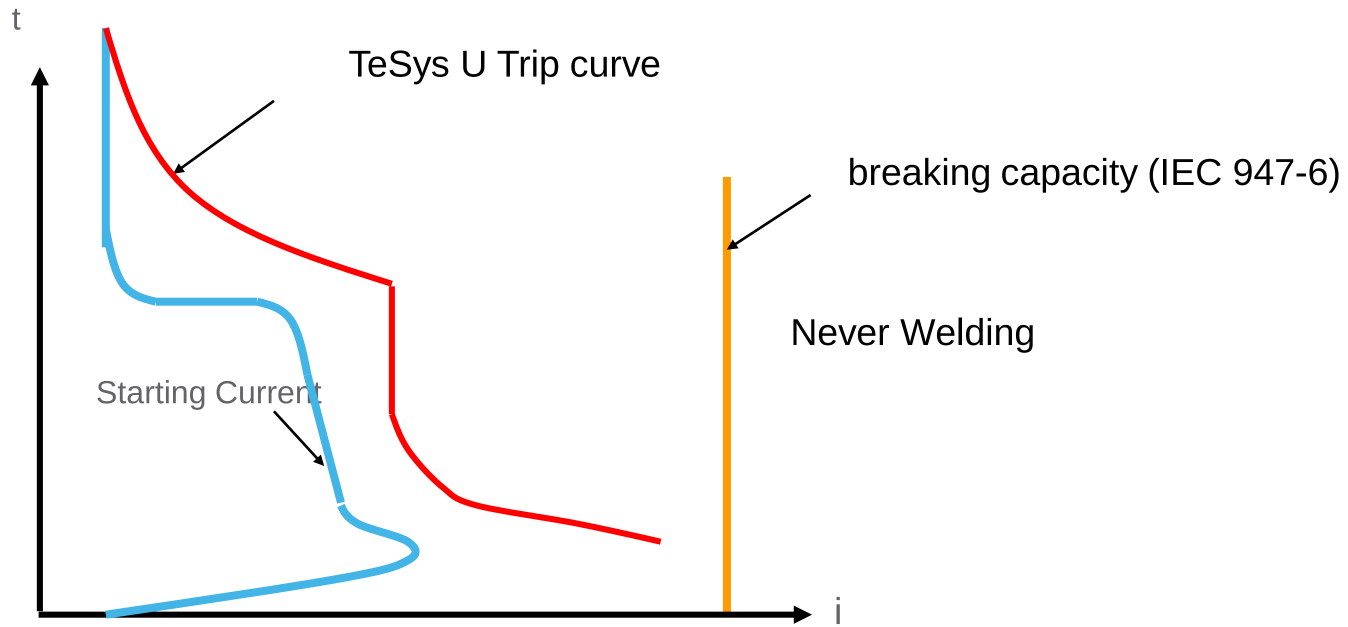
LC1 → Command



Coordination type: Total Coordination

TeSys U

Isolation
I>> Protection
Thermal Overload Protection
Command



Coordination of protective devices

- Without coordination
  - The risks are important for the personnel, the physiques and materials damages can be also important.

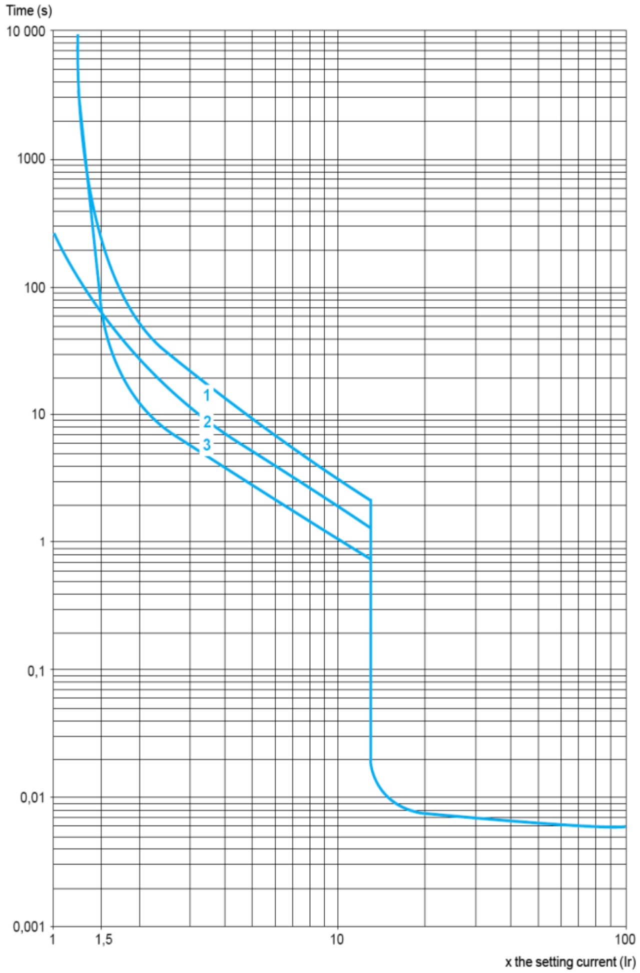
- Type 1 coordination
  - Without risk for the operator. It is the most standard solution used.
  - Before to restarting, the replacement of parts can be necessary.

- Type 2 coordination
  - It is the high performance solution. The risk of fusion of contacts is possible. In this case, the contacts must be easier separated.

- Total coordination, continuity of service
  - It is the higher performance solution.
  - No damage and no risk of fusion. Once the fault has been fixed, the motor starter must be able to restart immediately.

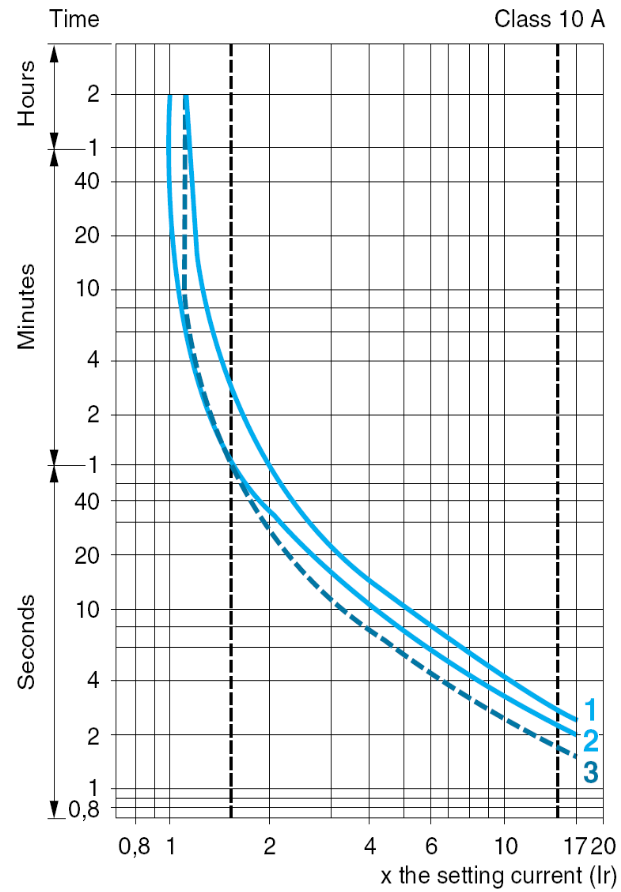
IEC 60947-4-1   I – T Curve

Motor Circuit Breaker



1 3 poles from cold state
2 2 poles from cold state
3 3 poles from hot state

Thermal Overload Rely



1 Balanced operation, 3-phase, from cold state.
2 2-phase operation, from cold state.
3 Balanced operation, 3-phase, after a long period at the set current (hot state).

Combination starters for customer assembly

TeSys motor starters - open version

D.O.L. starters with circuit-breaker and overload protection built into the circuit-breaker

0.06 to 110 kW at 400/415 V: type 1 coordination

Standard power ratings of 3-phase motors 50/60 Hz in category AC-3									Circuit-breaker		Contactor
400/415 V			440 V			500 V			Reference	Setting range of thermal trips	Reference *(2)*
P	Ie	Iq *(1)*	P	Ie	Iq *(1)*	P	Ie	Iq *(1)*			
kW	A	kA	kW	A	kA	kW	A	kA		A	
0.06	0.22	50	0.06	0.19	50	–	–	–	GV2 ME02	0.16…0.25	LC1 K06 or LC1 D09
			0.09	0.28	50						
0.09	0.36	50	0.12	0.37	50	–	–	–	GV2 ME03	0.25…0.40	LC1 K06 or LC1 D09
0.12	0.42	50	–	–	–	–	–	–			
0.18	0.6	50	0.18	0.55	50	–	–	–	GV2 ME04	0.40…0.63	LC1 K06 or LC1 D09
0.25	0.88	50	0.25	0.76	50						
0.37	0.98	50	0.37	0.99	50				GV2 ME05	0.63…1	LC1 K06 or LC1 D09
–	–	–	–	–	–	0.37	1	50			
0.55	1.5	50	0.55	1.36	50	0.55	1.21	50	GV2 ME06	1…1.6	LC1 K06 or LC1 D09
–	–	–	–	–	–	0.75	1.5	50	GV2 ME06	1…1.6	LC1 K06 or LC1 D09
0.75	2	50	0.75	1.68	50	–	–	–			
–	–	–	1.1	2.37	50	1.1	2	50	GV2 ME07	1.6…2.5	LC1 K06 or LC1 D09
1.1	2.5	50	–	–	–	1.5	2.6	50			
1.5	3.5	50	1.5	3.06	50	2.2	3.8	50	GV2 ME08	2.5…4	LC1 K06 or LC1 D09
2.2	5	50	2.2	4.42	50	–	–	–			
–	–	–	3	5.77	50	3	5	50	GV2 ME10	4…6.3	LC1 K06 or LC1 D09
3	6.5	50	–	–	–	4	6.5	10			
4	8.4	50	4	7.9	15	5.5	9	10	GV2 ME14	6…10	LC1 K09 or LC1 D09
5.5	11	15	5.5	10.4	8	7.5	12	6	GV2 ME16	9…14	LC1 K12 or LC1 D12
7.5	14.8	15	7.5	13.7	8	9	13.9	6			
–	–	–	9	16.9	8	–	–	–	GV2 ME20	13…18	LC1 D18
9	18.1	15	11	20.1	6	11	18.4	4	GV2 ME21	17…23	LC1 D25

Combination starters for customer assembly *(continued)*

TeSys motor starters - open version

D.O.L. starters with circuit-breaker and overload protection built into the circuit-breaker

0.06 to 110 kW at 400/415 V: type 2 coordination

Standard power ratings of 3-phase motors 50/60 Hz in category AC-3									Circuit-breaker		Contactor
400/415 V			440 V			500 V			Reference *(2)*	Setting range of thermal trips	Reference *(3)*
P	Ie	Iq *(1)*	P	Ie	Iq *(1)*	P	Ie	Iq *(1)*			
kW	A	kA	kW	A	kA	kW	A	kA		A	
0.06	0.22	130	0.06	0.19	130	–	–	–	GV2 P02 or GV2 ME02	0.16…0.25	LC1 D09
–	–	–	0.09	0.28	130	–	–	–			
0.09	0.36	130	0.12	0.37	130	–	–	–	GV2 P03 or GV2 ME03	0.25…0.4	LC1 D09
0.12	0.42	130	–	–	–	–	–	–			
0.18	0.6	130	0.18	0.55	130	–	–	–	GV2 P04 or GV2 ME04	0.4…0.63	LC1 D09
0.25	0.88	130	0.25	0.76	130	–	–	–			
0.37	0.98	130	0.37	0.99	130	–	–	–	GV2 P05 or GV2 ME05	0.63…1	LC1 D09
–	–	–	–	–	–	0.37	1	130			
0.55	1.5	130	0.55	1.36	130	0.55	1.21	130	GV2 P06 or GV2 ME06	1…1.6	LC1 D09
–	–	–	–	–	–	0.75	1.5	130	GV2 P06 or GV2 ME06	1…1.6	LC1 D09
0.75	2	130	0.75	1.68	130	–	–	–			
–	–	–	1.1	2.37	130	1.1	2	130	GV2 P07 or GV2 ME07	1.6…2.5	LC1 D09
1.1	2.5	130	–	–	–	1.5	2.6	130			
1.5	3.5	130	1.5	3.06	130	2.2	3.8	130	GV2 P08 or GV2 ME08	2.5…4	LC1 D09
			–	–	–	–	–	–			
2.2	5	130	–	–	–	–	–	–	GV2 P10 or GV2 ME10	4…6.3	LC1 D09
–	–	–	2.2	4.42	50	–	–	–			
–	–	–	3	5.77	50	3	5	50	GV2 ME10	4…6.3	LC1 D09
–	–	–	2.2	4.42	130	–	–	–			
–	–	–	3	5.77	130	3	5	130	GV2 P10	4…6.3	LC1 D09
3	6.5	130	–	–	–	–	–	–			
4	8.4	130	–	–	–	–	–	–	GV2 P14 or GV2 ME14	6…10	LC1 D09
–	–	–	4	7.9	15	4	6.5	10			

THANK YOU