Basic of Low Voltage Soft Starter

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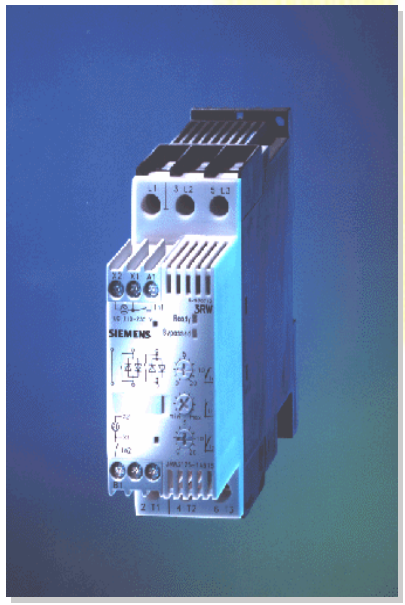
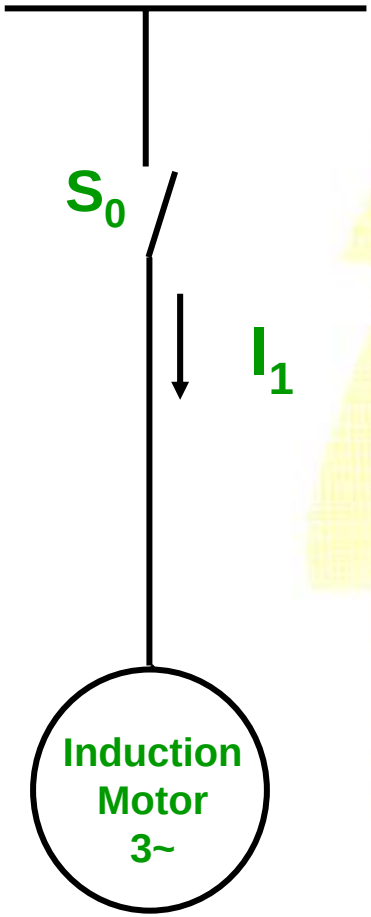


Starting Methods for AC Motor

- **Direct-on-line starting (DOL.)**
- **Star-Delta starting (Y-Δ)**
- **Reactor starting or Auto-transformer starting**
- **Part-winding starting**
- **Rotor resistance starting (slip ring)**
- **Variable speed drive**
- **Soft Starting by Electronic Controller So Call Soft Starter**



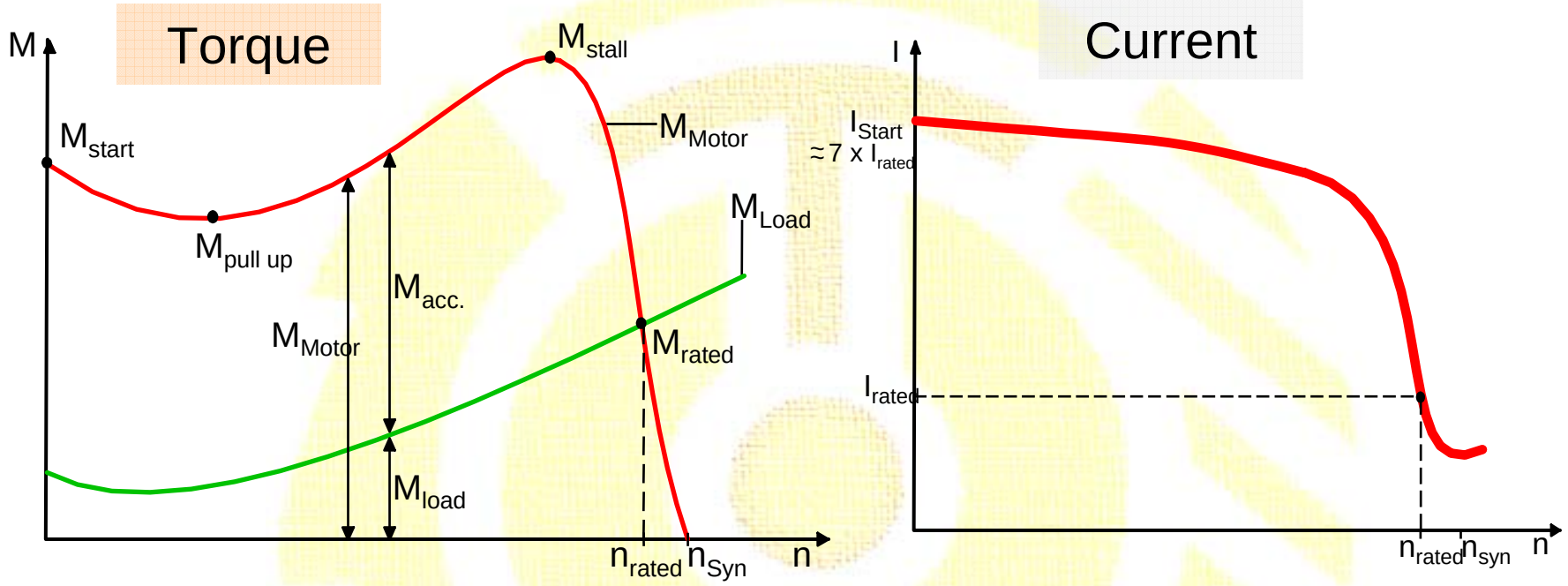
Advantages:

- ✓ Lowest costs for breakers and auxiliaries; simple installation, hence low capital costs.
- ✓ Develop maximum starting torque.
- ✓ System conditions permitting, direct-on-line starting should therefore always be preferred.

Disadvantages:

- ✗ Starting current is about 4 to 7 times the motor rated current, depending on motor power rating and speed.
- ✗ Voltage drop when motor is switched on. Lower the line power and/or the higher the multiple of the motor rated current, the larger will be voltage drop.

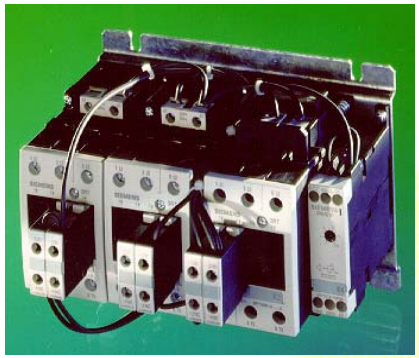
Ways to start a motor Direct online Start (DOL)

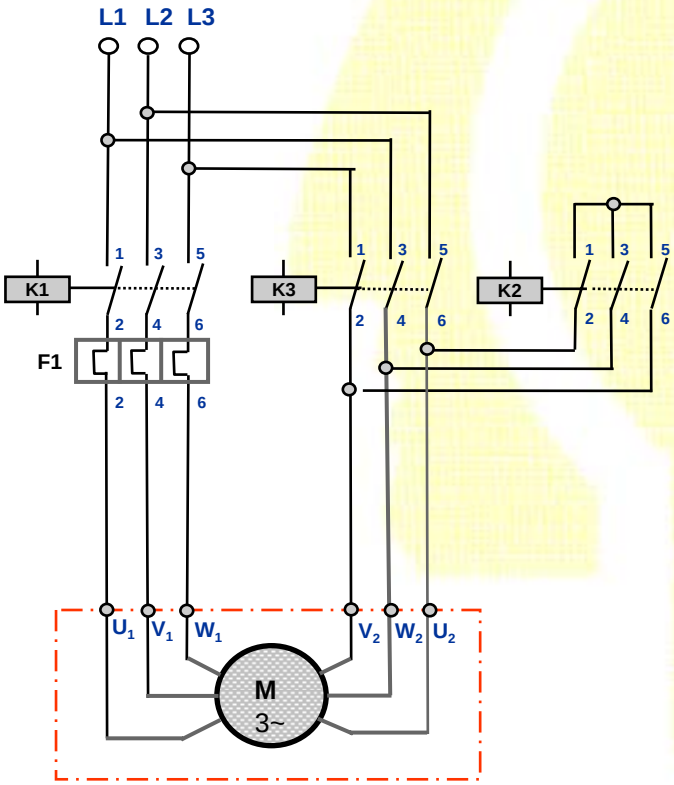


- DOL-Torque causes stress to the motor and to the load
  - increasing maintenance costs
  - shorter maintenance periods

- DOL-current causes stress to the motor and to the line
  - take effect to the dimensioning of the line
  - take effect to the dimensioning of the switchgears

Ways to start a motor Star-Delta starting





Advantages:

✓Starting current is reduced to approx. 33% of the values encountered if the motor was started across the line.

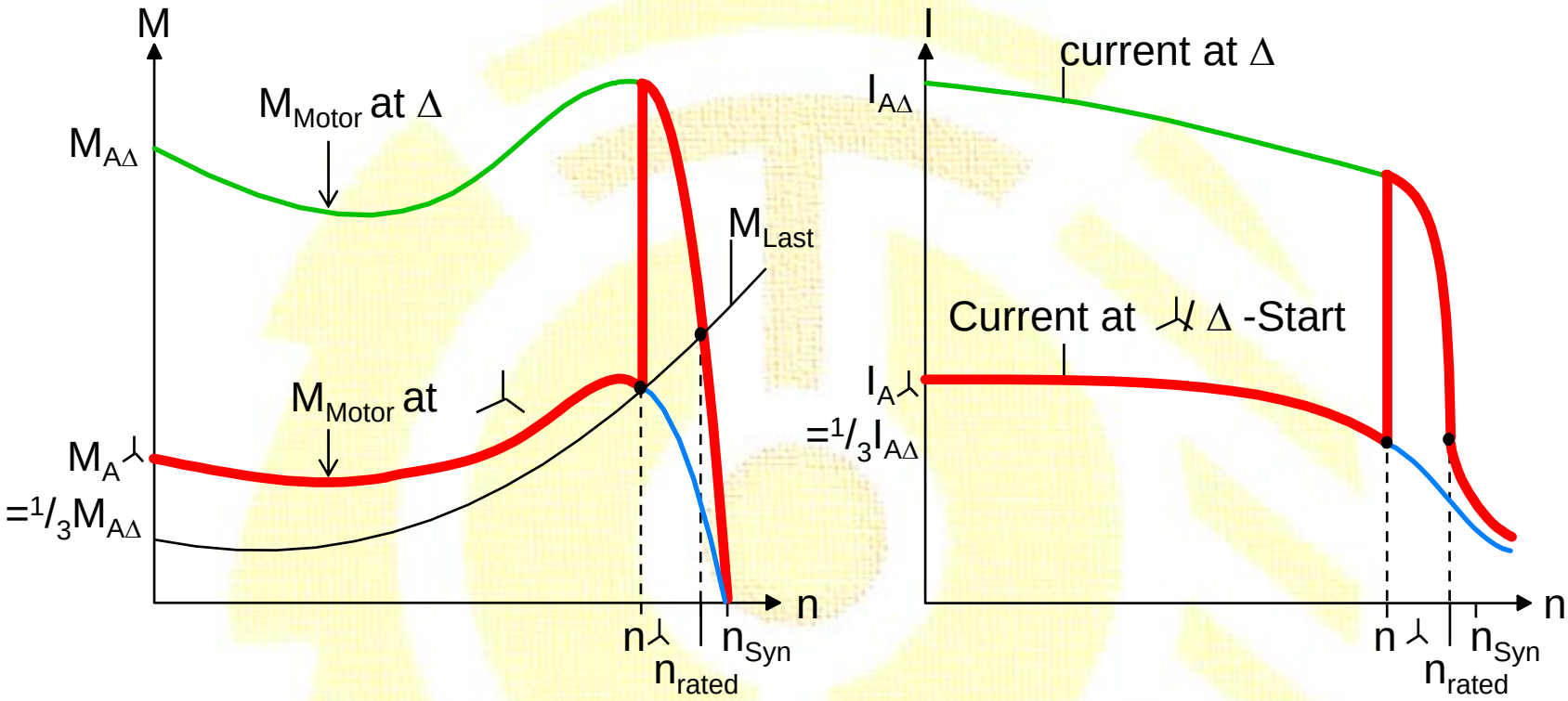
Disadvantages:

✕Torque ($\propto V^2$) is also reduced to 1/3.

Remark:

Mainly use in low voltage motor.

Ways to start a motor Star-Delta starting



- torque-peek causes stress to the motor and to the load
  - increasing maintenance costs
  - shorter maintenance periods

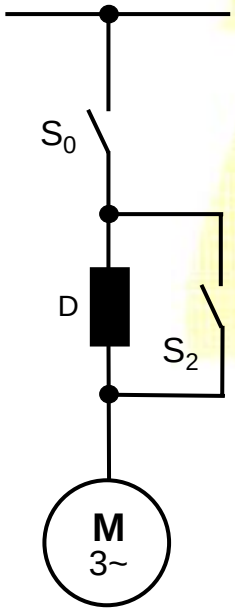
- current peek causes stress to the motor and to the line
  - take effect to the dimensioning of the line
  - take effect to the dimensioning of the switchgears

Part winding starting

Some squirrel cage motors have two or more stator windings which are connected in parallel during normal operation. During starting, only one winding is connected.

This increases stator impedence and reduces starting current. Such a starting scheme is called *part winding starting.*

Starting by Reactor or Auto-Transformer



$I \sim M^2$

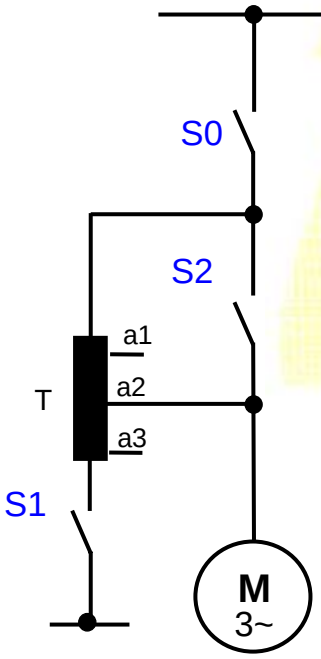
When the current is linearly reduced, the torque is reduced according to a square law

Switching sequence:

1) Breaker S_0 is closed, the motor starts via the reactor.

2) After starting, the reactor coil is by-passed by breaker S_2.

Starting by Reactor or Auto-Transformer



I ~ M

Starting current (line side) and starting torque
decrease in the same ratio.

Switching sequence:

1) The motor starts via the starting transformer with breakers
S_0 and S_1 closed. Bypass breaker **S_2** is open.

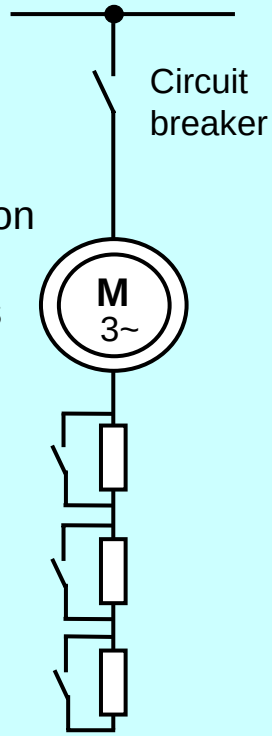
2) Breaker S1 is only opened after the motor has accelerated, and then bypass breaker **S_2** is closed.

The costs involved are significant which makes it more expensive than reactor starting.

Rotor Resistance starting Methods

+ Circuit breaker
+ Engineering costs
+ Mounting/installation
+ Service/ maintenance costs

+ Series resistors



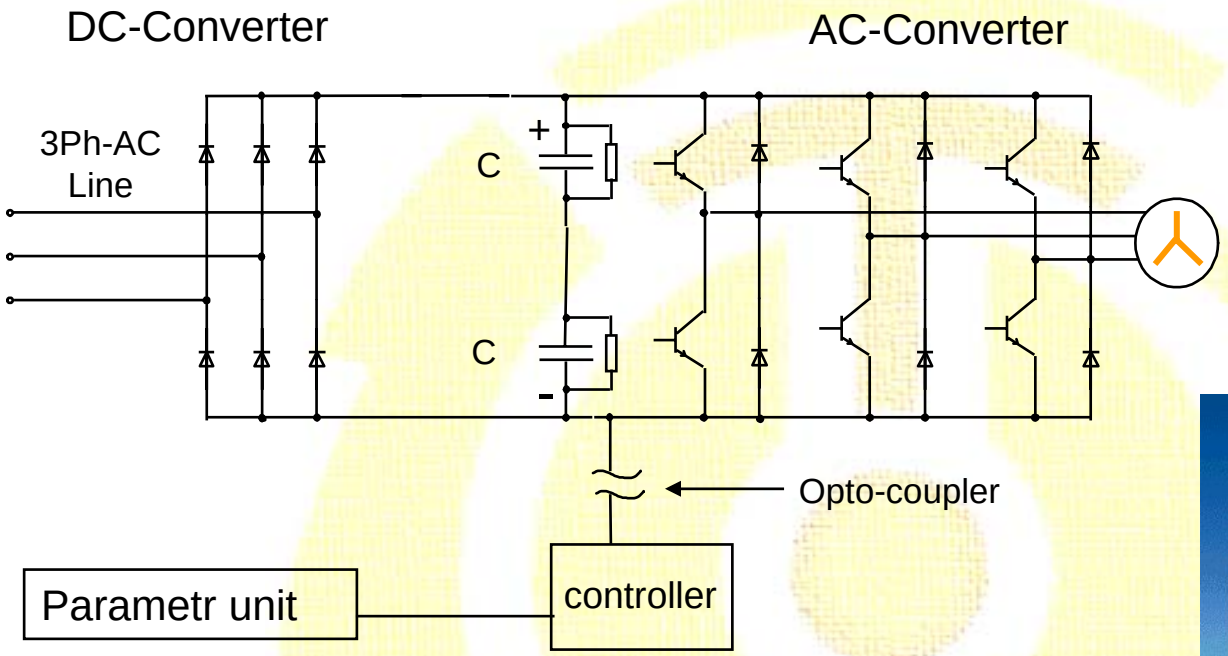
Advantages:

- **Important feature is that the starting torque and torque-to-current ratio are high. It is, therefore, suitable for applications requiring starting with heavy load and starting with high inertia load.**
- **While maximum torque is independent of rotor resistance value, speed at which maximum torque is produced can be controlled by changing the value of external resistors.**

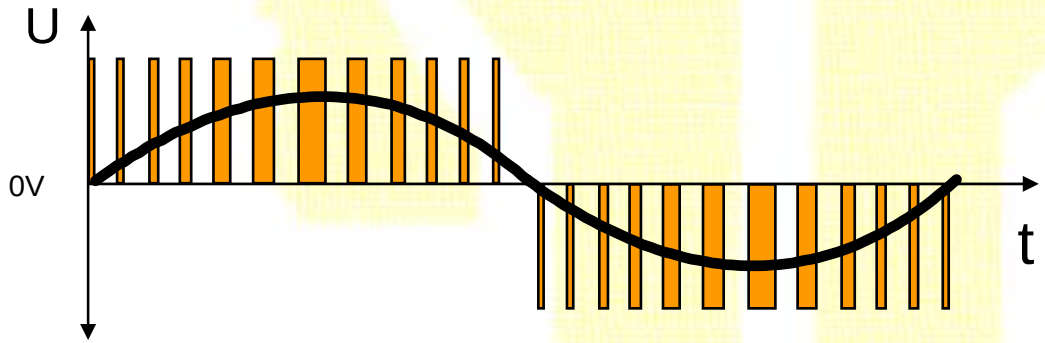
Disadvantages:

✕ **Higher maintenance of slip ring motor is required.**

Ways to start a motor Inverter starting

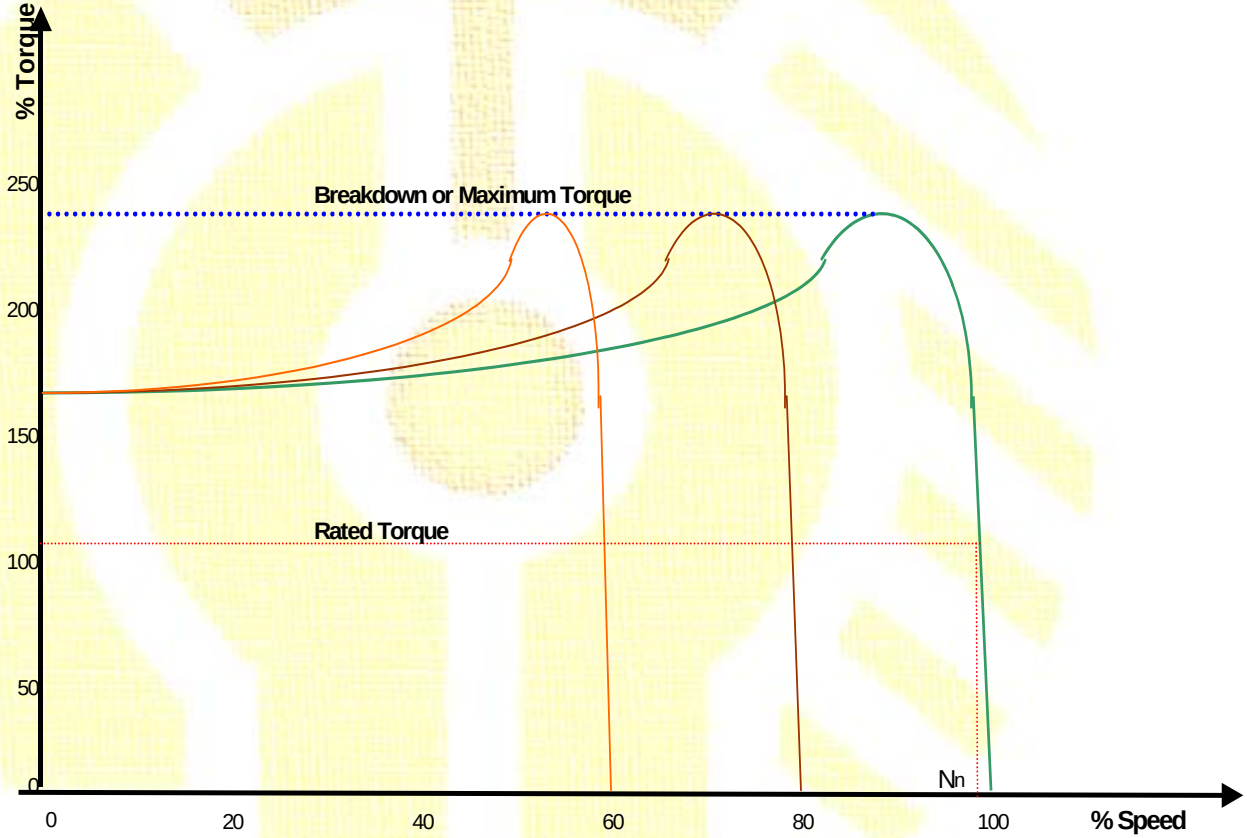


Complicated Electronics and Expensive way

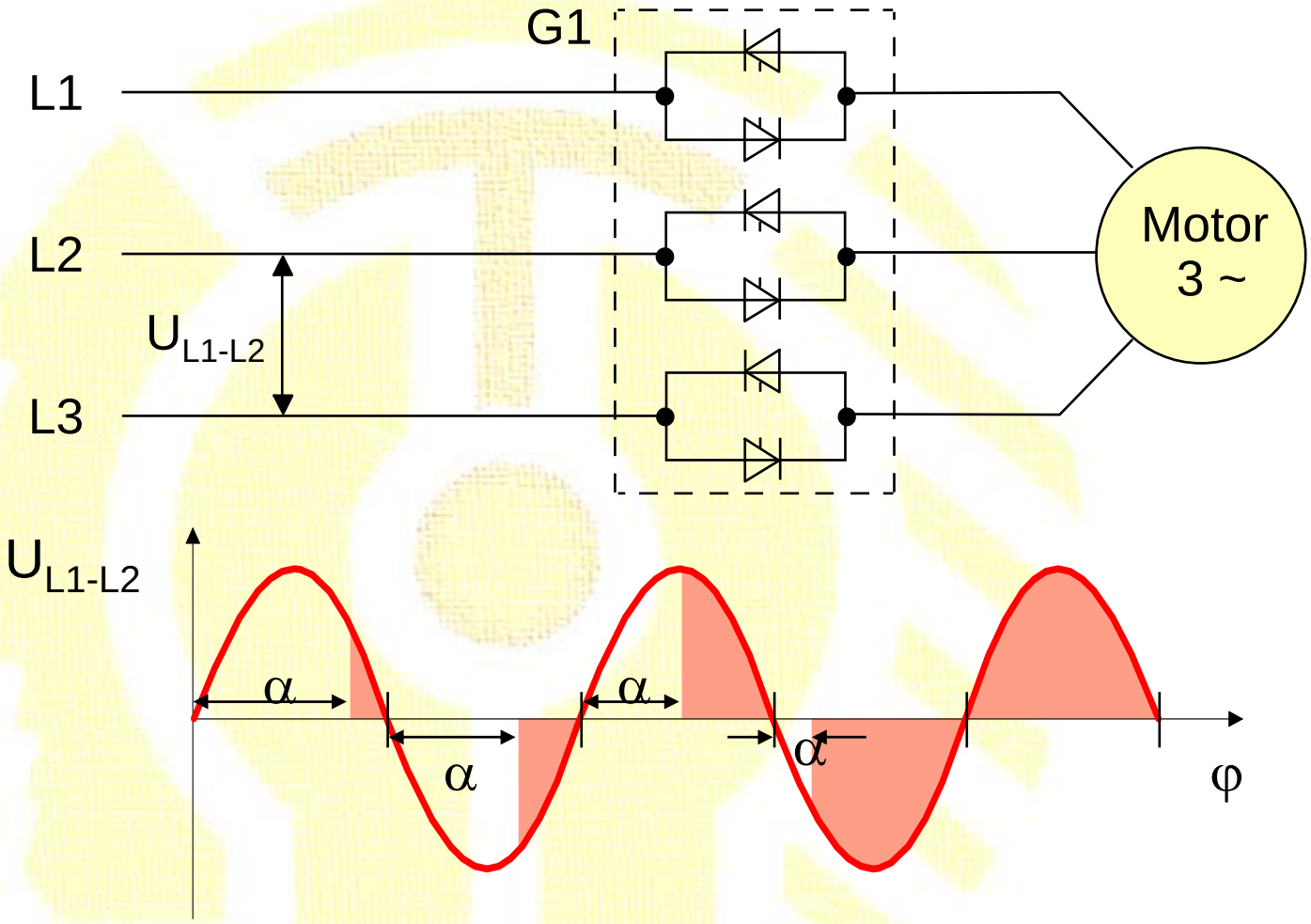


Inverter can produce Voltage with changed amplitude and frequency

Ways to start a motor Inverter starting



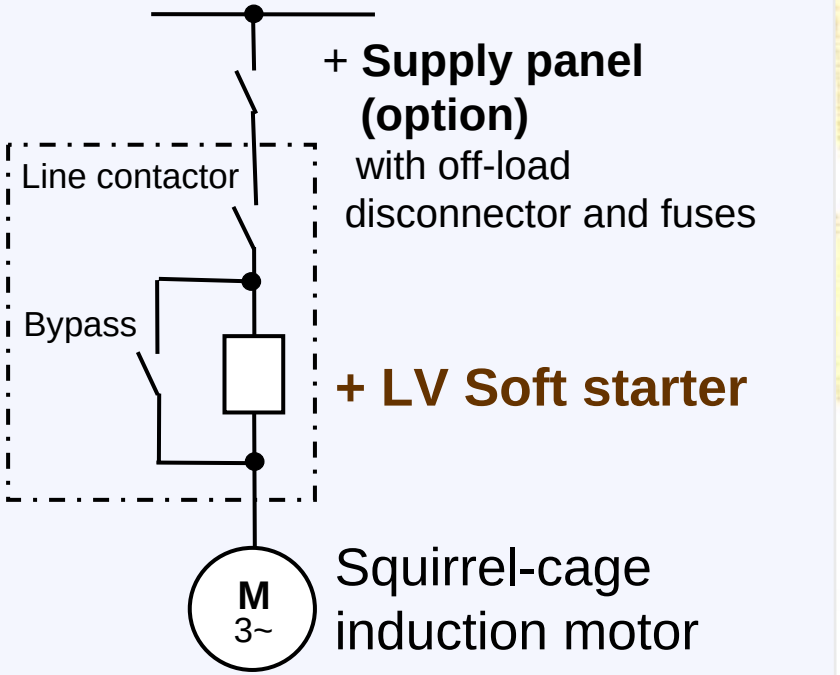
Ways to start a motor Soft Starter



Power electronics in 1, 2 or 3 controlled phases

Reduction of the voltage via phase-angle-control

System comparison, LV SST to reactor starting



+ **Supply panel (option)** with off-load disconnector and fuses

+ LV Soft starter

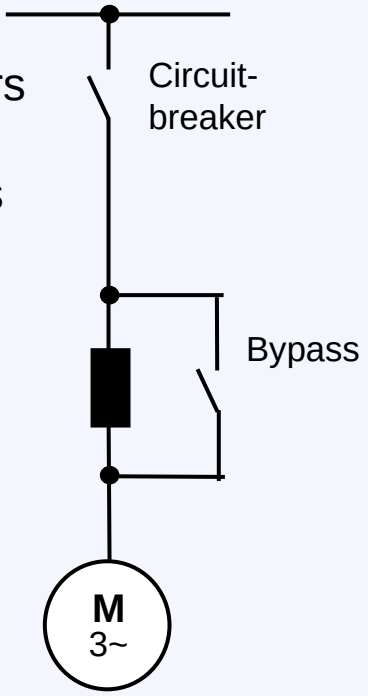
Squirrel-cage induction motor

+ 2x Circuit Breakers

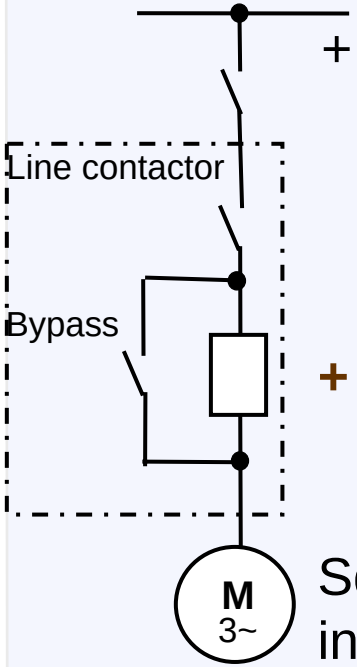
+ Engineering costs
+ Mounting/ installation

+ Starting reactor

Squirrel-cage induction motor



System comparison, Soft Starter to transformer starting



+ Supply panel (option) with off-load disconnector and fuses

+ Soft Starter

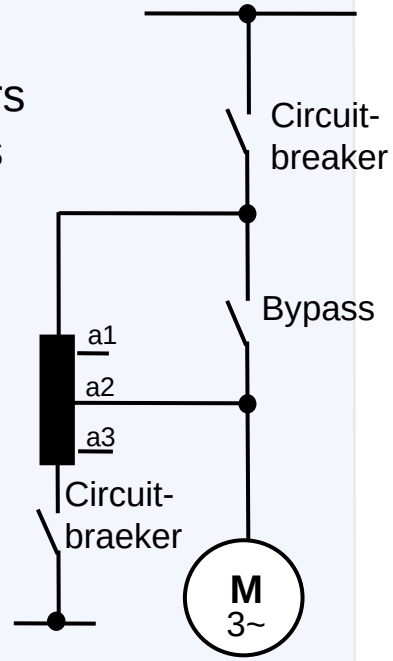
Squirrel-cage induction motor

+ 3x Circuit Breakers
+ Engineering costs
+ Mounting/ installation

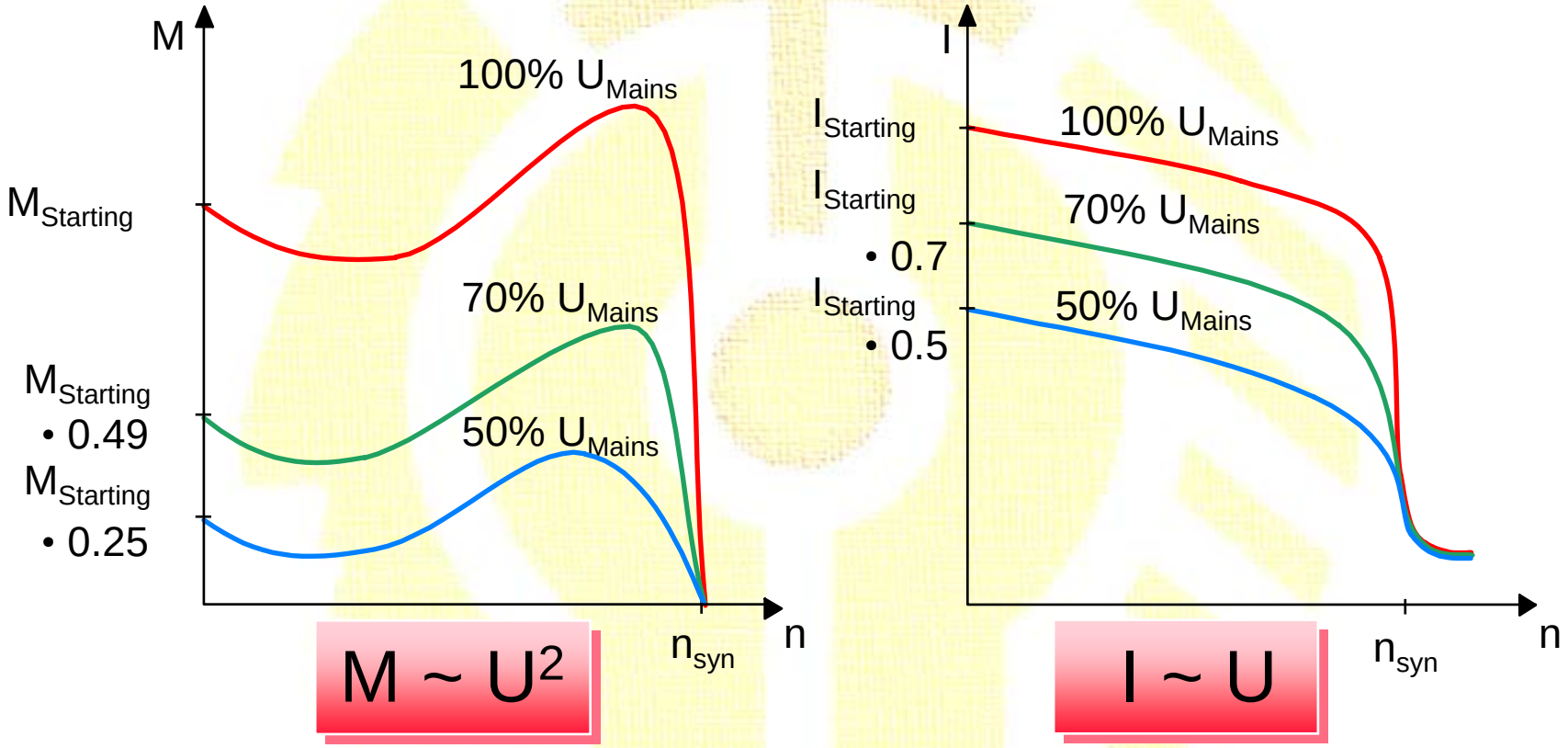
+ Starting

transformer

Squirrel-cage induction motor

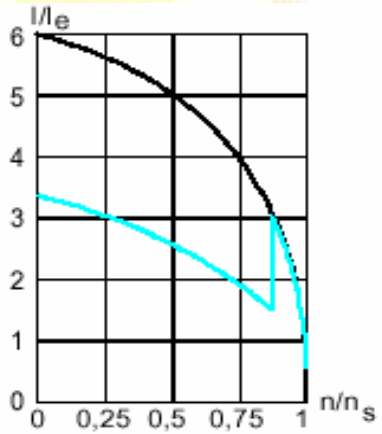


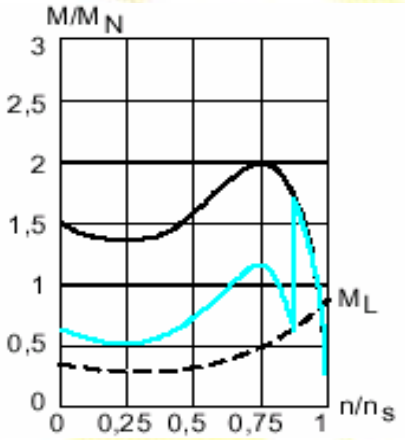
Ways to start a motor Soft Starter



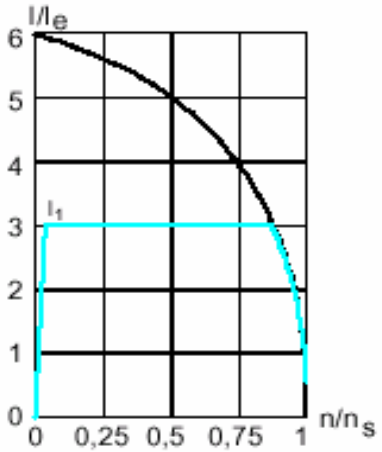
The current and torque characteristics

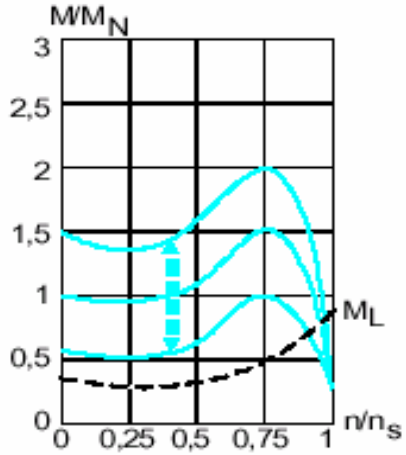
Starting transformer





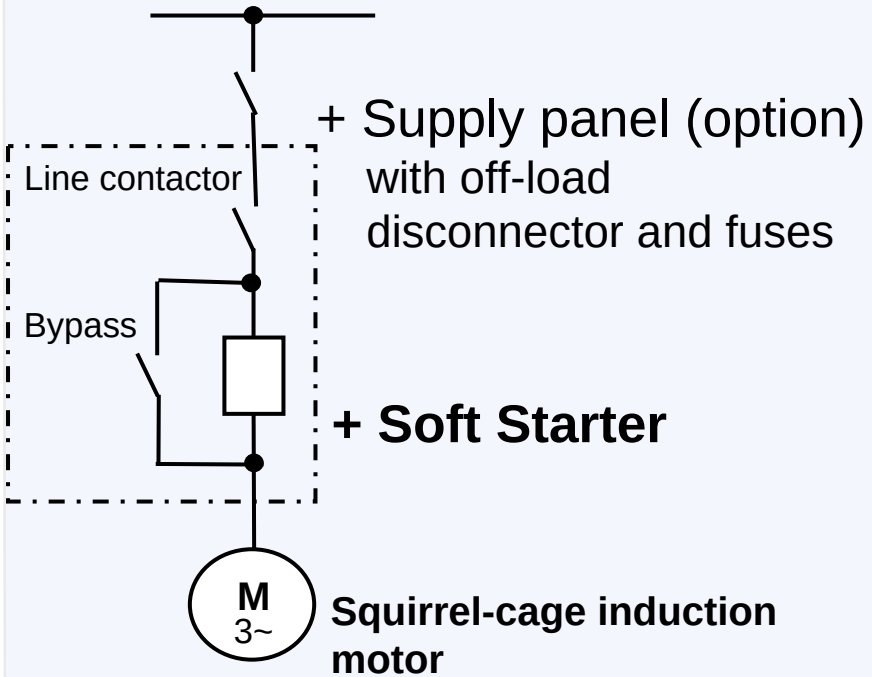
Soft starting





High current peaks can still be identified for starting transformers.

System comparison, MV SST squirrel-cage induction motor with slipring rotor motor with starter



+ Supply panel (option) with off-load disconnector and fuses

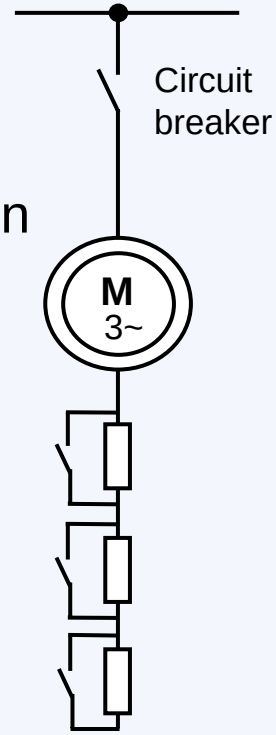
+ Soft Starter

Squirrel-cage induction motor

+ Circuit Breaker
+ Engineering costs
+ Mounting/installation
+ Service/ maintenance costs

+ Series resistors

Slipring rotor motor

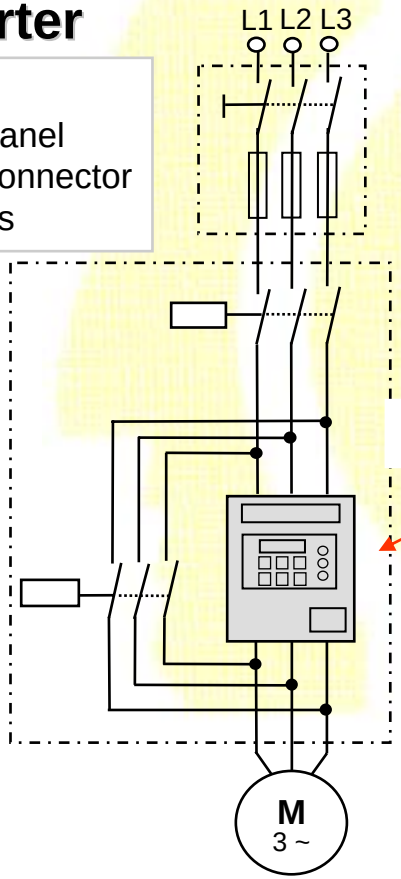


Compared with conventional starting Equipment Slipring motor with starter

Squirrel-cage induction motor — Slipring rotor

Softstarter

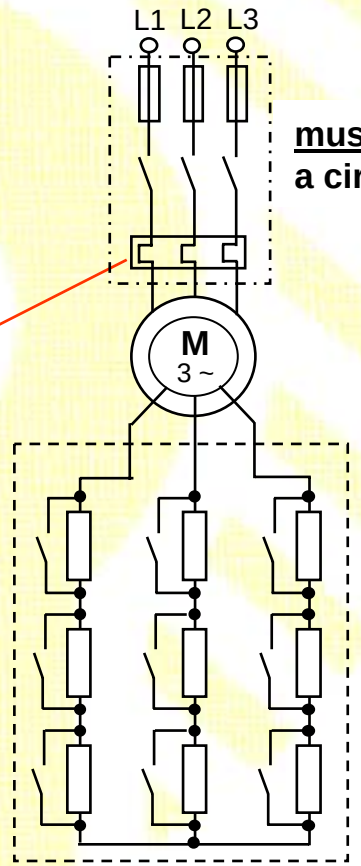
Option:
Supply panel with disconnector and fuses



Overcurrent protection

Starter

must be a circuit-breaker!



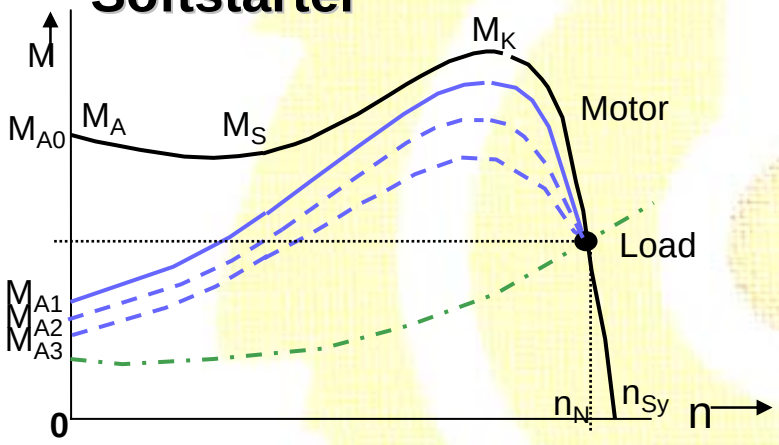
Series Resistors in the star configuration

Compared with conventional starting Equipment Slipring motor with starter

Squirrel-cage induction motor

Slipring motor

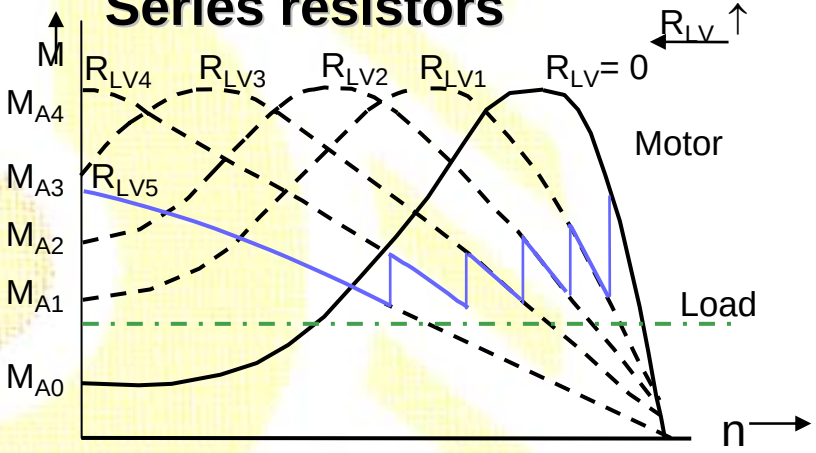
Softstarter



Soft starter reduces the starting torque

$$\frac{M_A}{M_N} = 0{,}25 \text{ to } 1$$

Series resistors



The starting torque is adjusted by matching the starting resistance to the rotor resistance.

$$\frac{M_A}{M_N} = 0{,}25 \text{ bis } \frac{M_K}{M_N} \text{ (approx.2,5-3,5)}$$

Compared with conventional starting Equipment Slipring motor with starter

Squirrel-cage induction motor

Softstarter

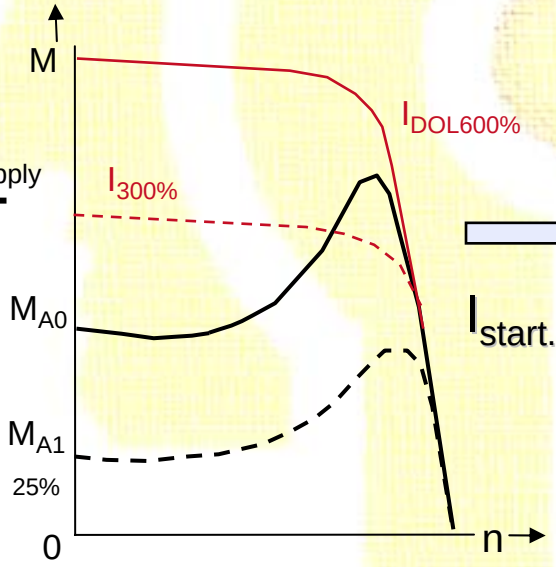
$I_{start} \sim V_{start}$

$M_{start} \sim V_{start}^2$

Starting torque 25% M_N

$\Rightarrow V_{start} = \frac{V_{supply}}{2}$

$\Rightarrow I_{start} = \frac{I_{DOL}}{2}$



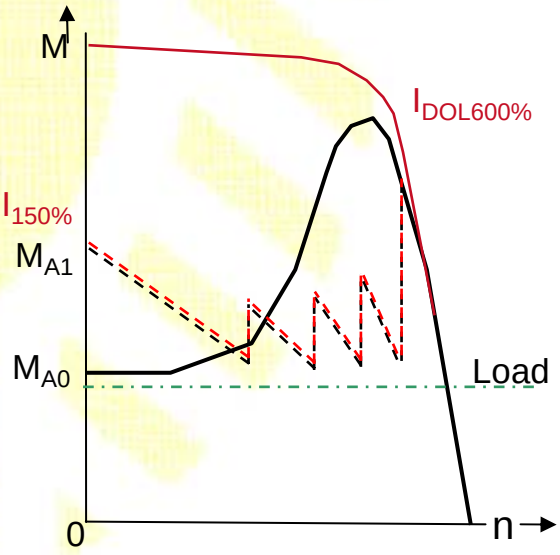
$I_{start.} = 0.25\ I_{DOL}$

Slipring motor

Series resistors

$I_{start} \sim M$

Starting torque 25% M_N



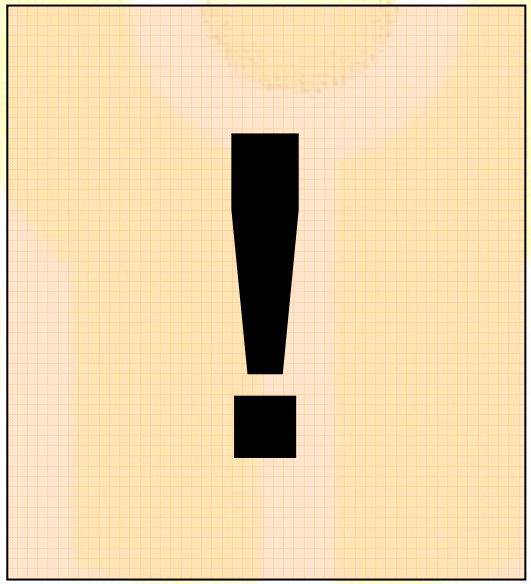
Load characteristics

Different loads

have

Different load-characteristics.

To know this different characteristics is very important to select the right soft starter !!!!!!

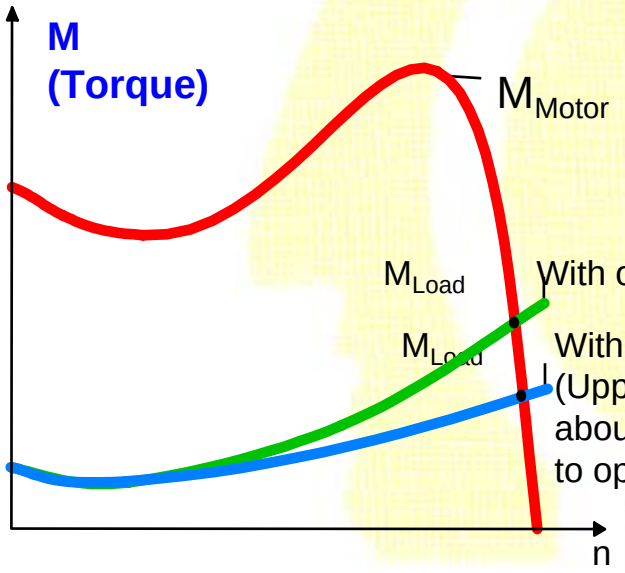


Load characteristics

Example:
Pumps, ventilators

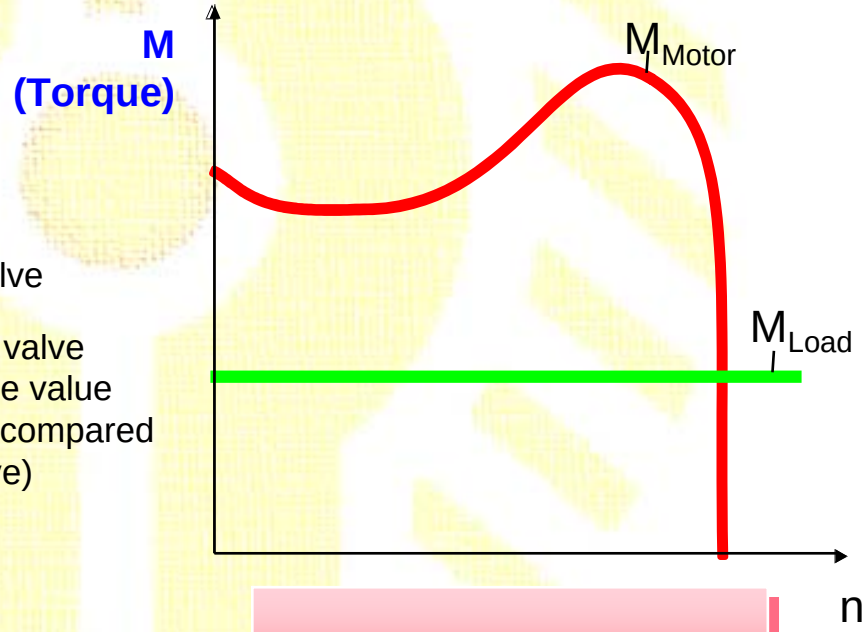
Example:
Hoists, conveyor- belts

Square-law load torque:



$M_{Load} \sim n^2$

Constant load torque:

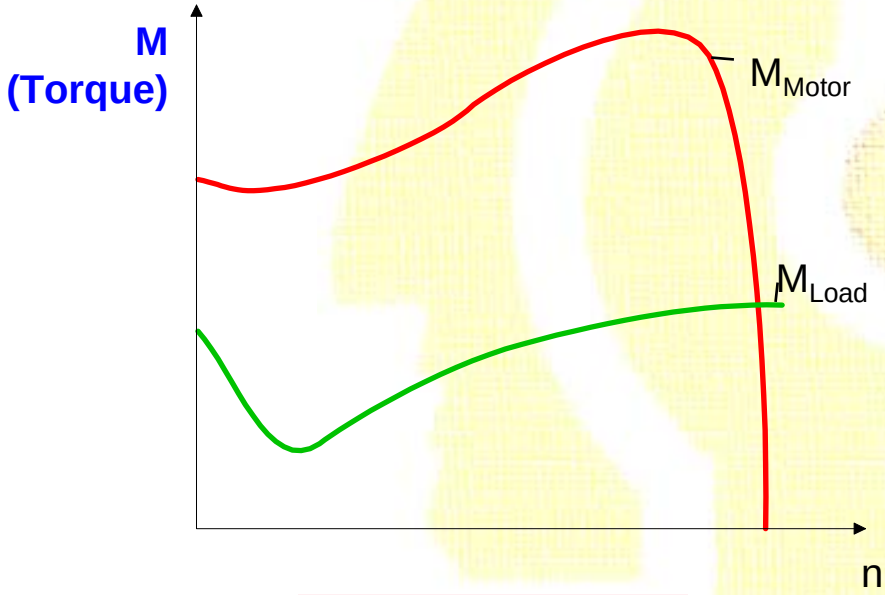


$M_{Load} = const.$

Load characteristics

Example:
Mills, crushers

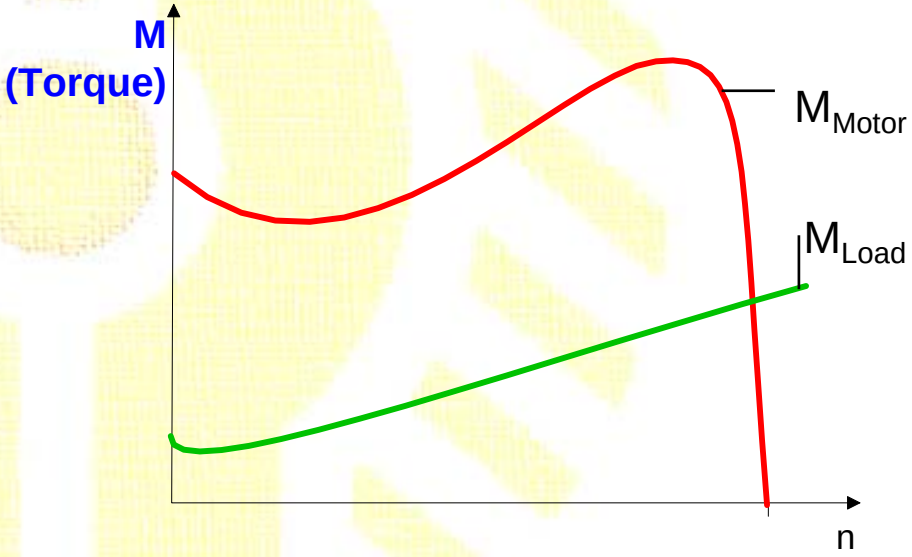
Load torque inversely proportional to rotational speed:



$M_{Load} \sim {}^{1}/_{n}$

Example:
Rotary irons, calenders

Load torque with linear rise:



$M_{Load} \sim n$

Problems faced by customers using conventional starters

> 35% - over current (surge)

> 20% - under current

> 40% - water hammering

Starting time too long - O/L

Mechanical breakage - Belts

Stopping time too long

Cost of inverters too high

Solved by Soft Starters