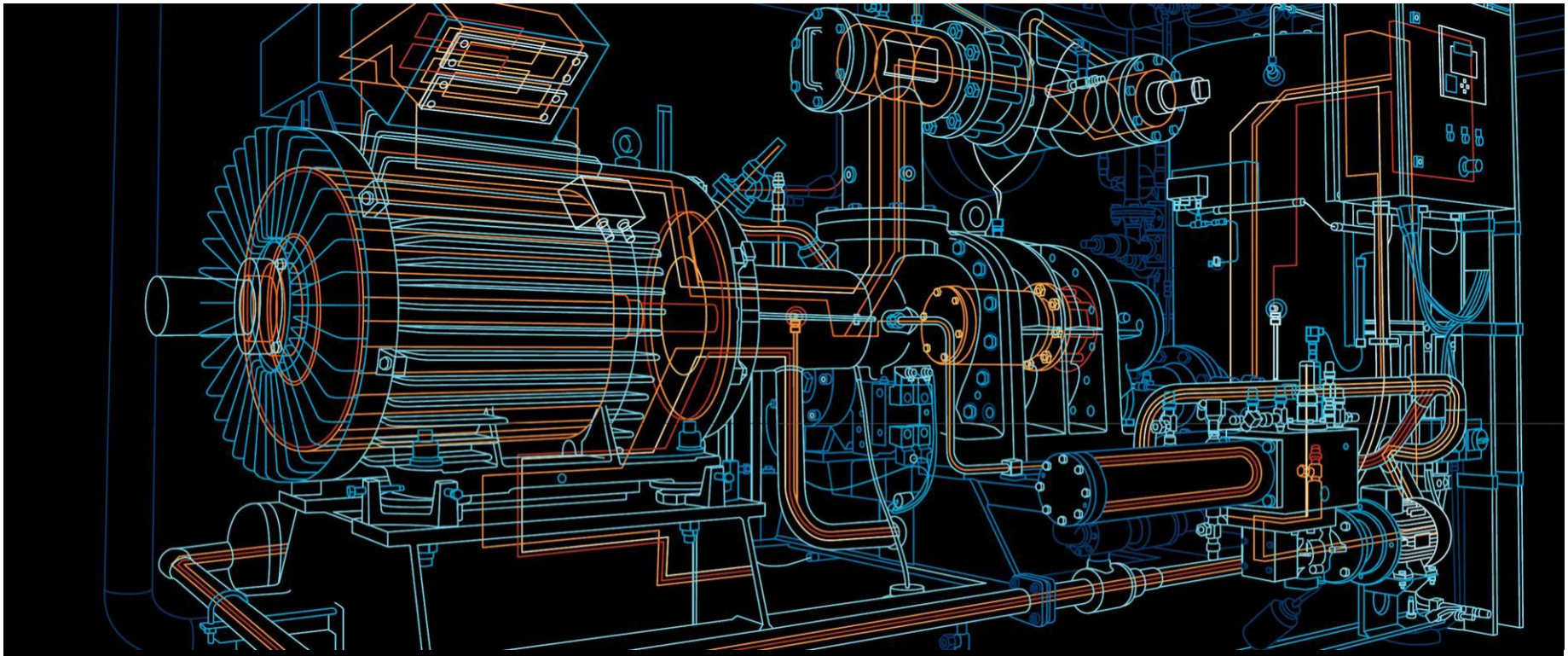
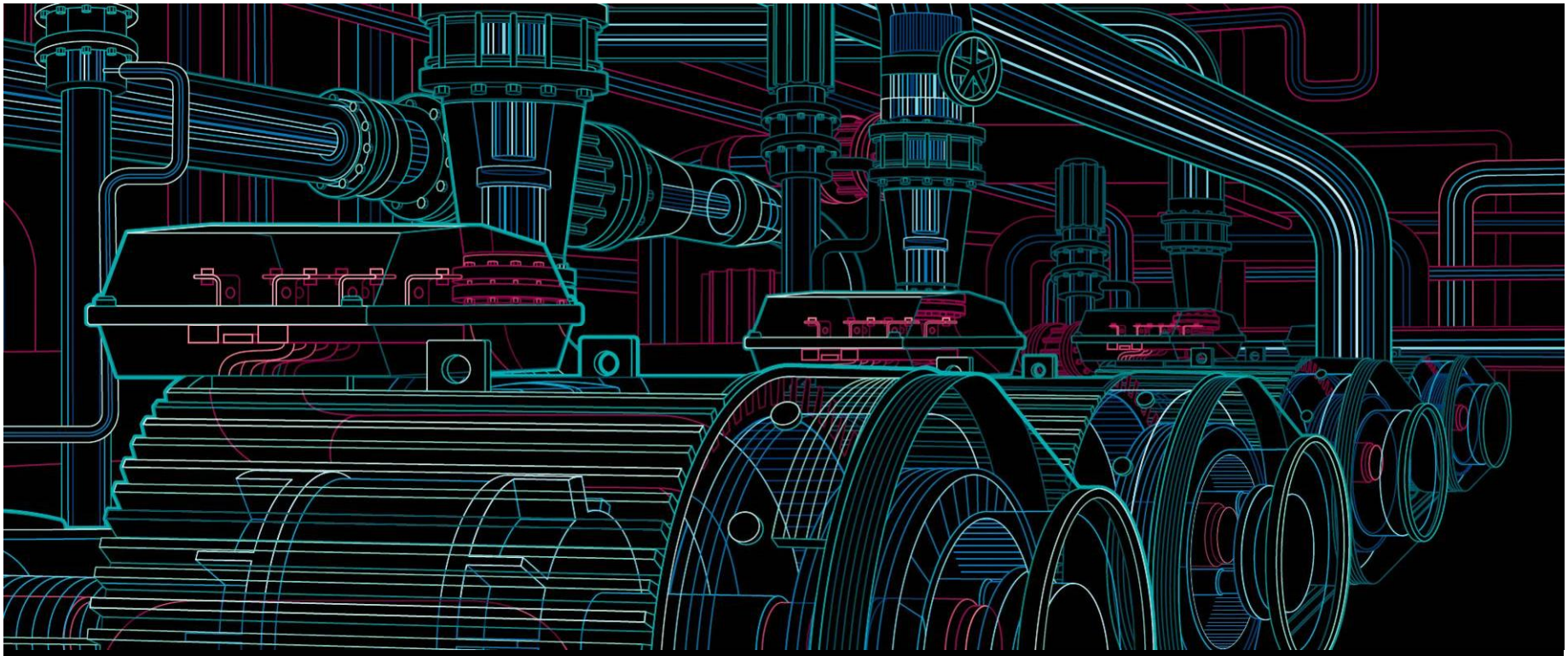


ONG Peck Seng, LEE Kok Hong, GOH Liak Teck, EP, 2016

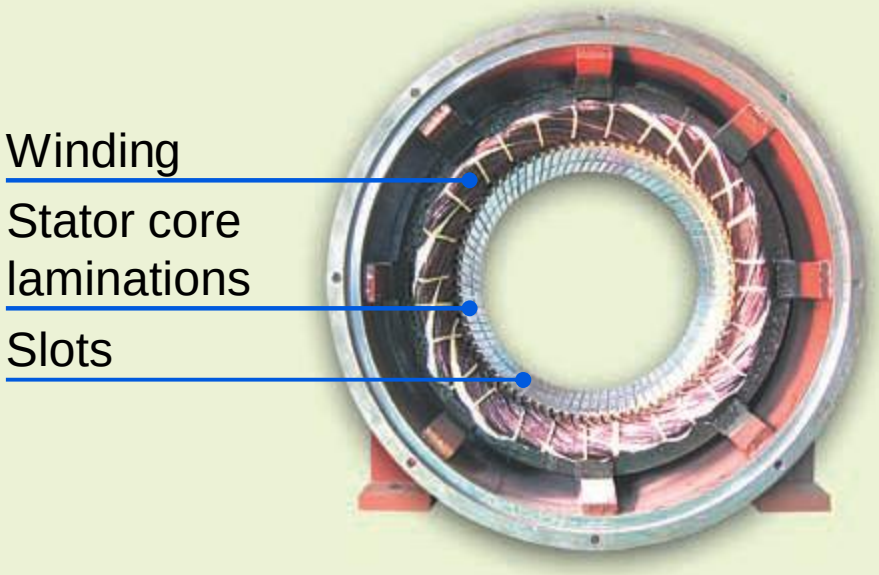
Efficient Motor Starting Solutions
The Various Methods of Manual Motor Starting

Power and productivity
for a better world™



Motor Starter Appreciation
What is an electric motor

Motor Starter Appreciation
Main parts of an electric motor



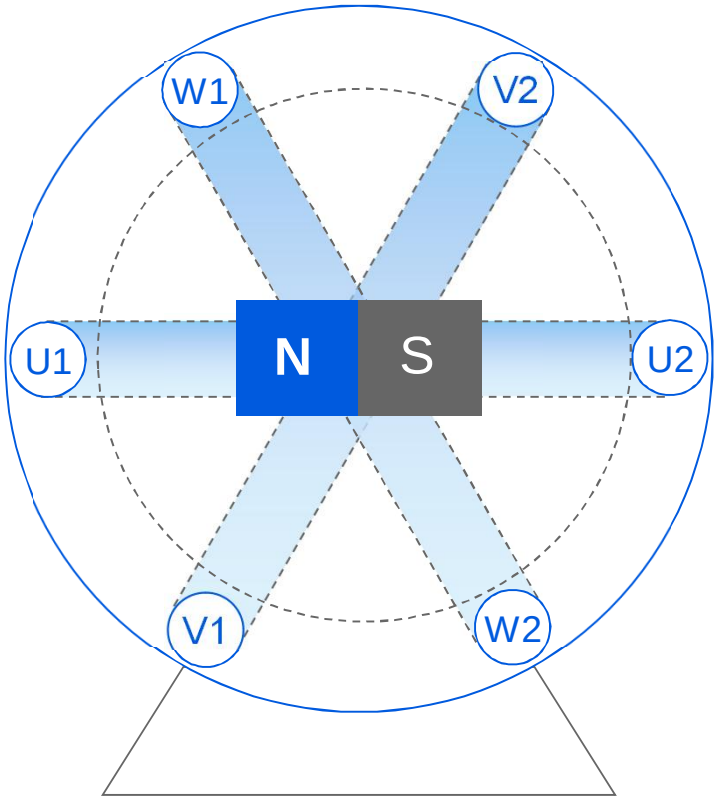
Stator



Rotor

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Motor Starter Appreciation
Generating three-phase in an electric motor



speed n = $\frac{120\ f}{p}$

frequency f = 50 Hz

speed n = 3000 rev/min

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Motor Starter Appreciation
What is an electric motor?

Electrical Energy



Mechanical Energy

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Motor Starter Appreciation
Electric motors consume 70% of world's generation



Power Generation



Step up Transformer



Transmission



Step down Transformer



Switch Gear



Circuit Breaker



Contactor



Protection

Motor Starter



Motor



Mechanical System

80% for Singapore

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Motor Starter Appreciation
Why is it important?

42%
of all electricity is used by the industry

2/3
of this is used by electrical motors

=

28%
of global electricity consumption

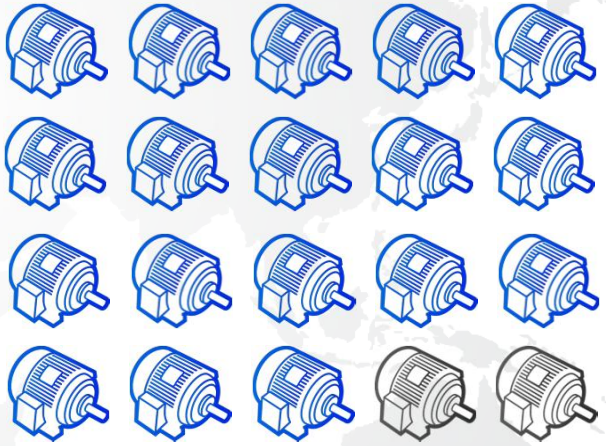


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Motor Starter Appreciation
Why is it important?

300,000,000
electrical motors are
currently installed worldwide.

90% are used in full-speed
applications.



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Motor Starter Appreciation
Some industrial apps where electric motors are applied



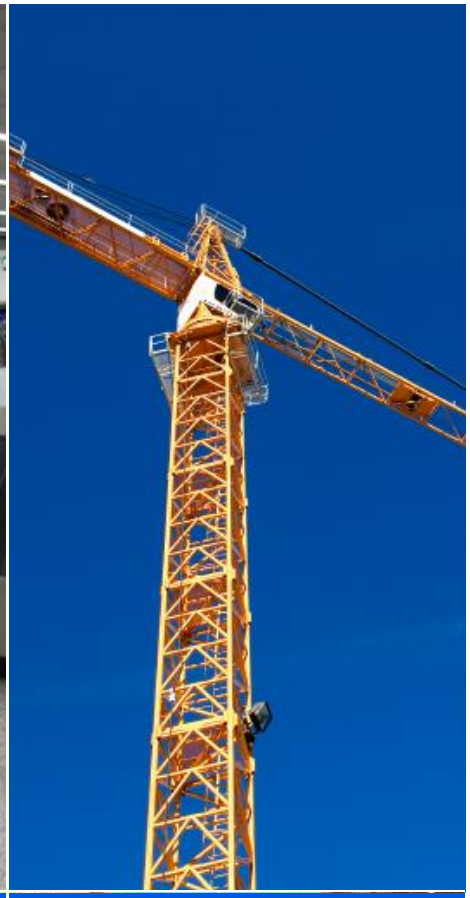
Bow Thrusting



Pumping / Fan



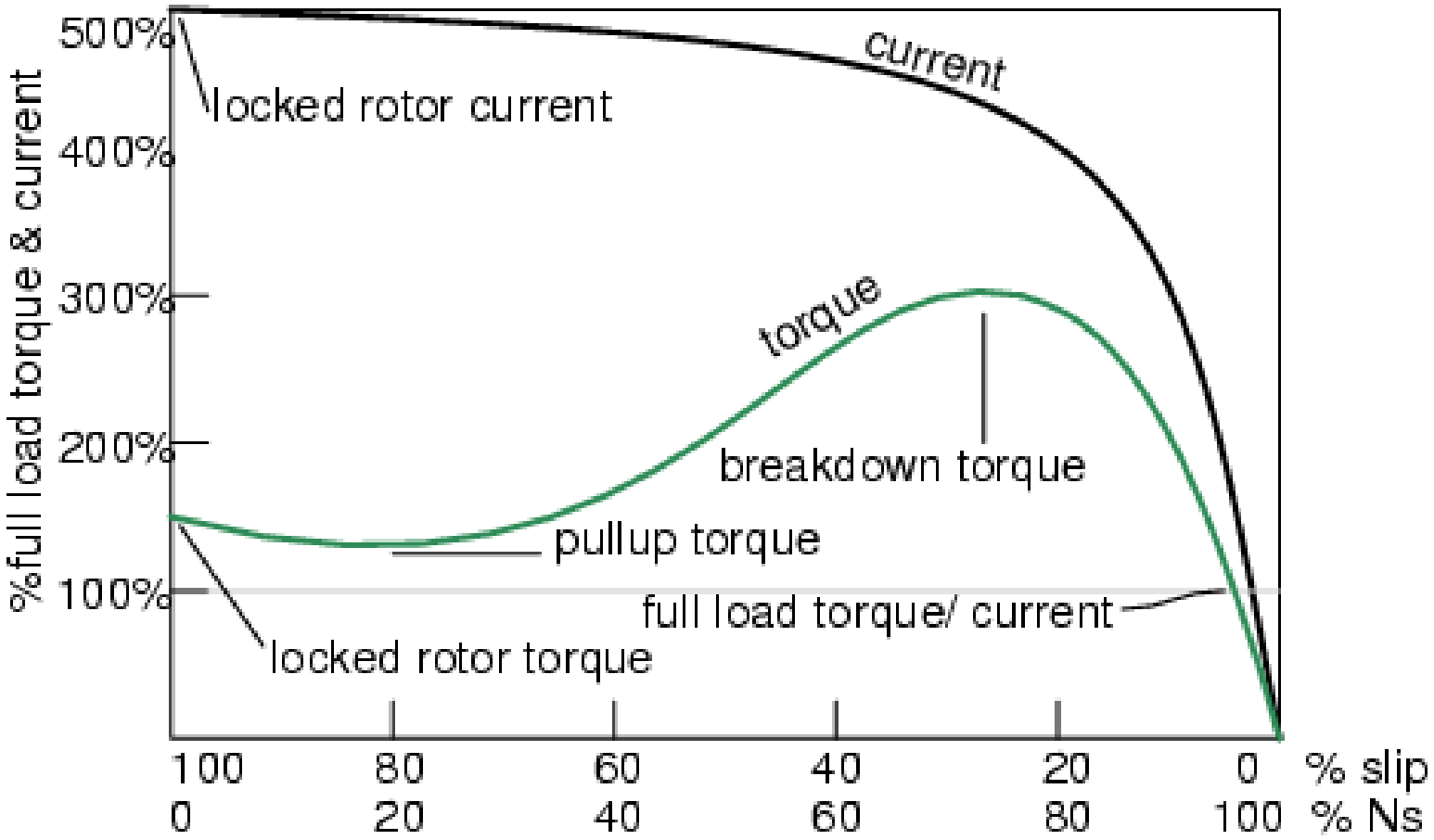
Material Handling



Hoisting / Winching

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Motor Starter Appreciation
Torque-speed curve of 3-phase a.c. induction motor

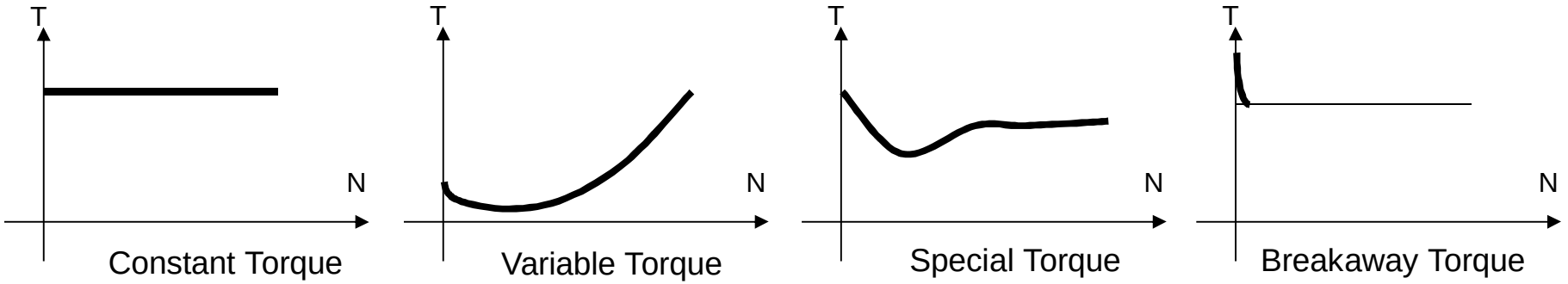


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Motor Starter Appreciation
Mech. Consideration: Load torque curves



1. Constant Torque
2. Variable Torque
3. Special Torque
4. High Starting / Breakaway Torque
5. Others



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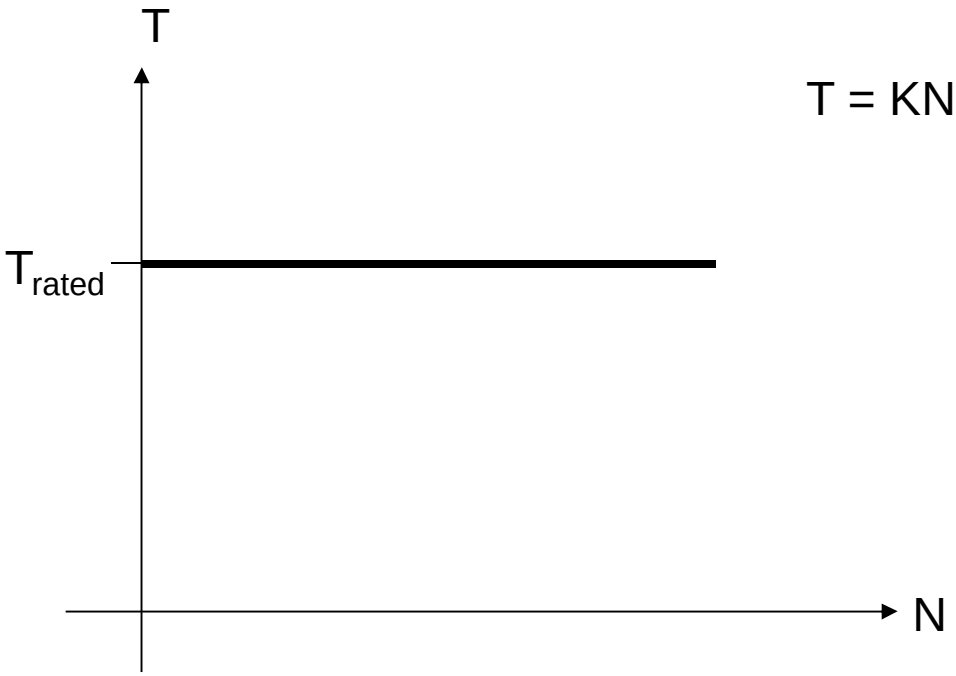
Motor Starter Appreciation
Constant torque applications



Characteristics

- Almost same torque through out the whole speed range
- High starting torque needed
- Mainly for conveying and material handling







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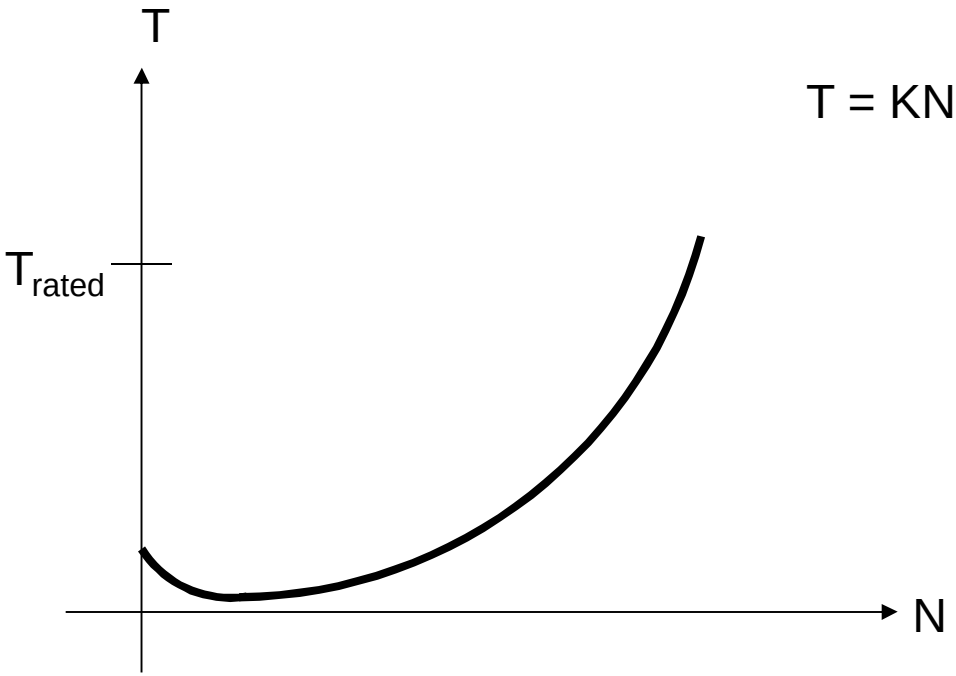
Motor Starter Appreciation
Variable torque applications



Characteristics

- Torque is the square function of speed
- Low starting torque
- Centrifugal machine





$T = KN^2$



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Motor Starter Appreciation
Special torque applications

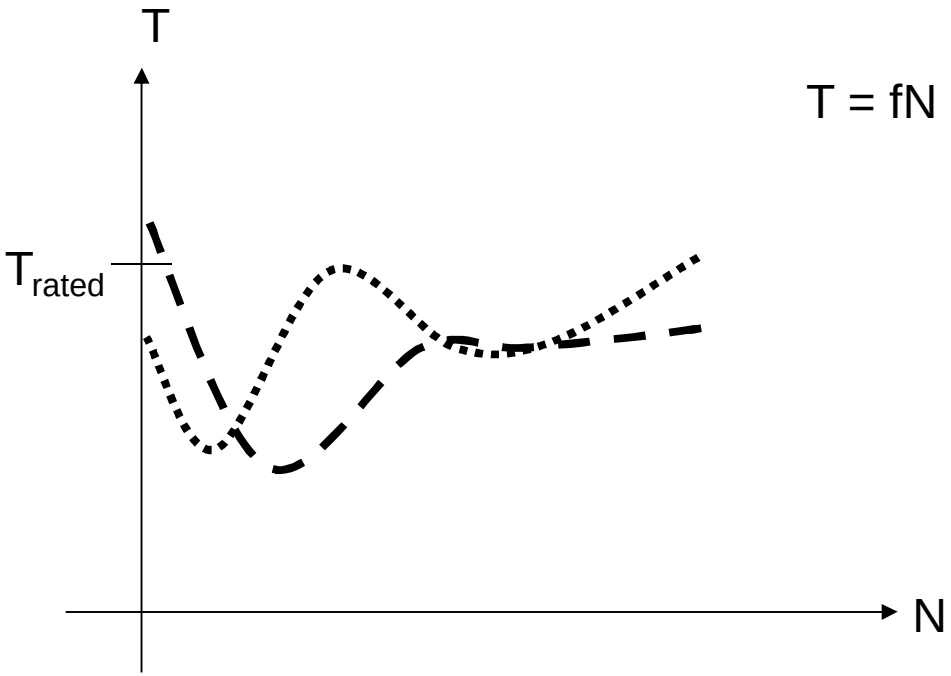


Characteristics

- Torque is non linear and high variation to speed
- High starting torque
- High frictional machine / Hoisting / Grinding







T = fN

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Motor Starter Appreciation
High starting / Breakaway torque applications

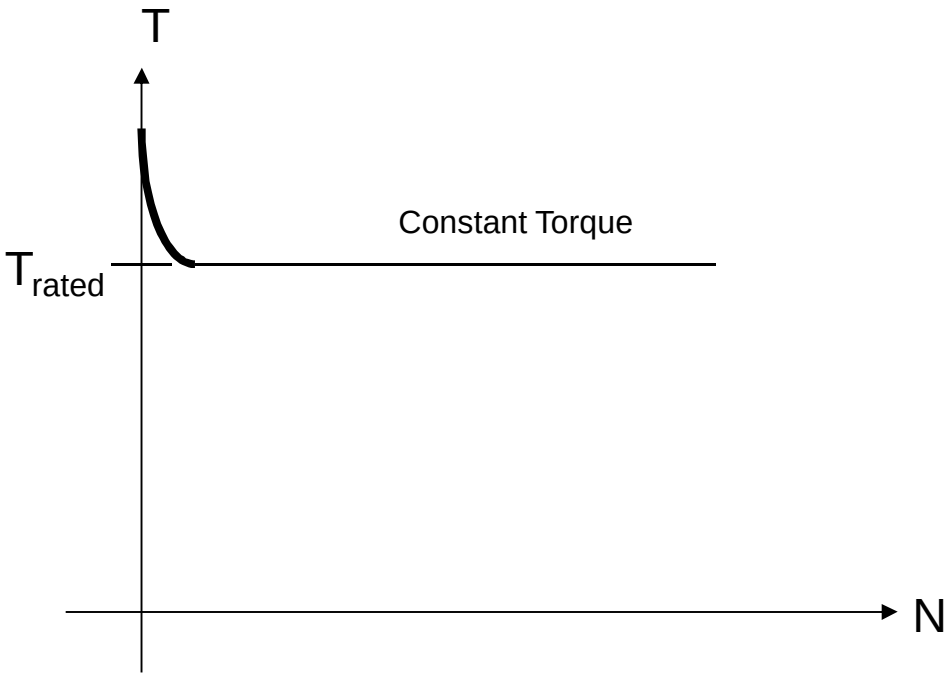


Characteristics

- Breakaway torque could be few times the rated torque (rare case, due to static friction)
- Must consider when selecting motor starters
- Extrusion machines, screw pumps



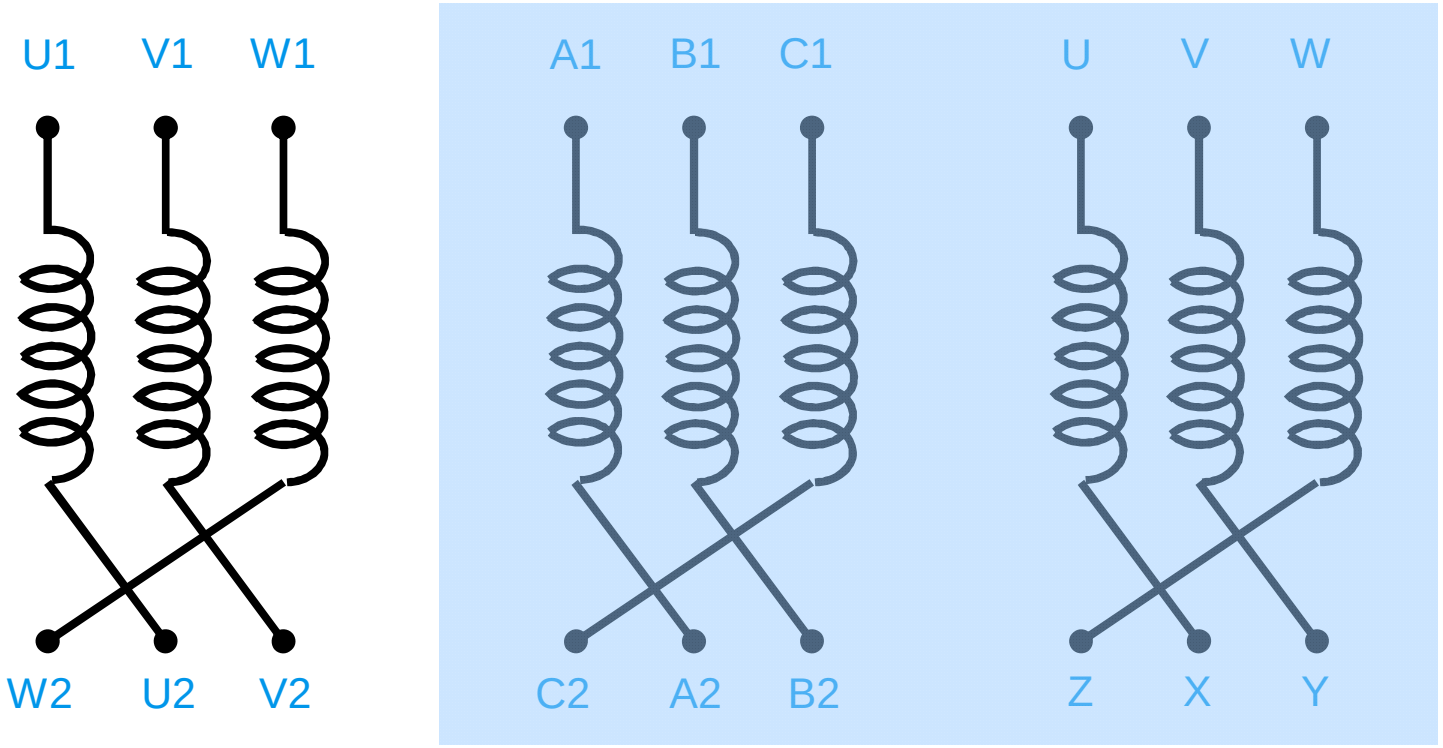




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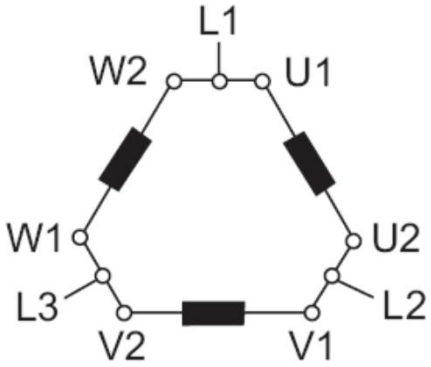
Motor Starter Appreciation
Terminals on an asynchronous motor

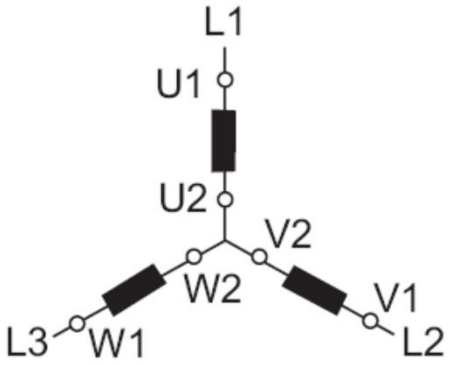
- The most common layout of the motor terminals in an actual situation

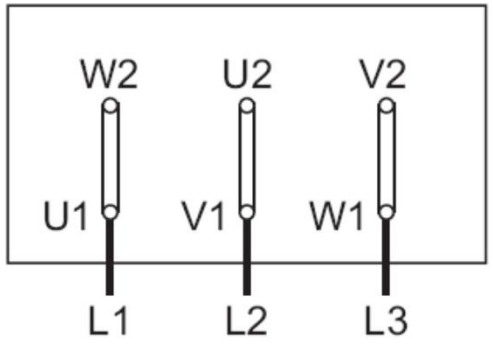


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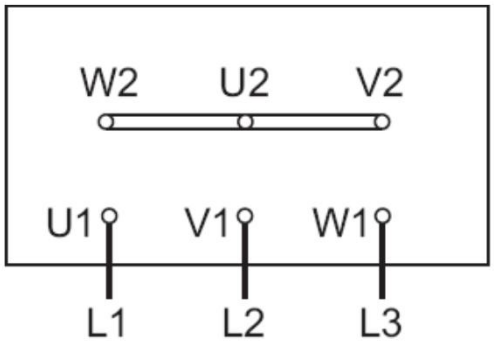
Motor Starter Appreciation
Winding connection







△ – Connection
230 V
(400 V)



Y – Connection
400 V
(690 V)

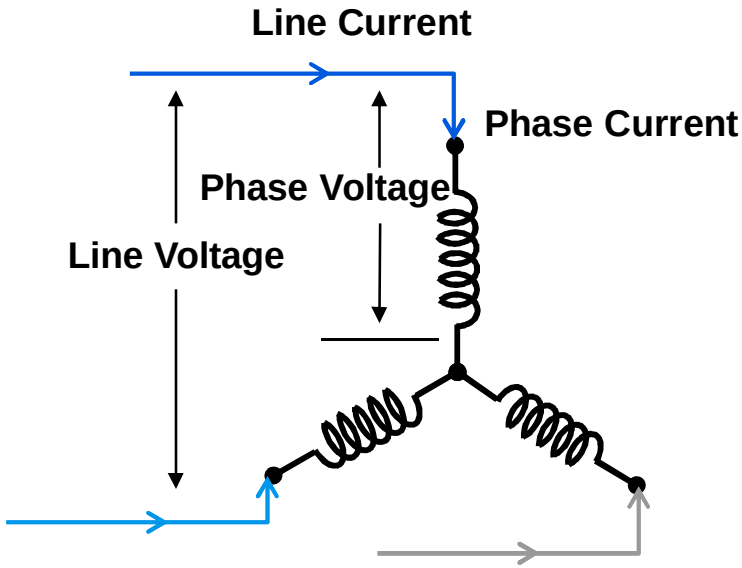
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Motor Starter Appreciation
Voltage and current relationship



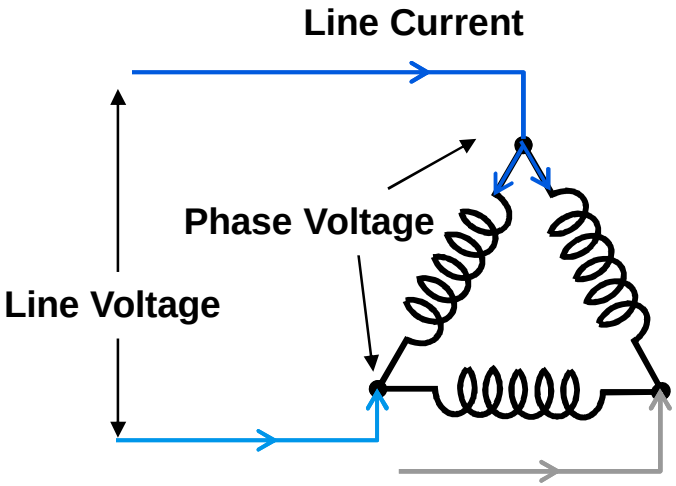
In STAR connection

Line Voltage = √3 Phase Voltage
Line Current = Phase Current

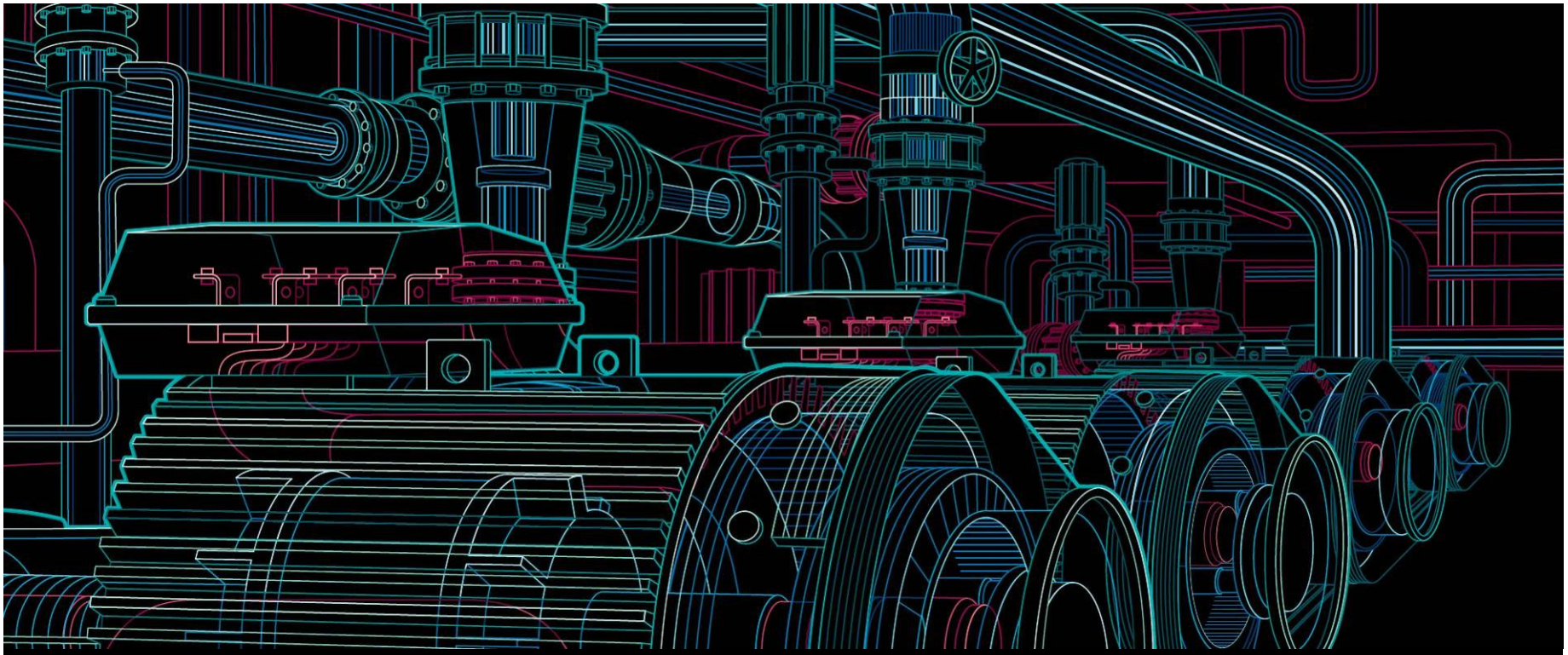


In DELTA connection

Line Voltage = Phase Voltage
Line Current = √3 Phase Current



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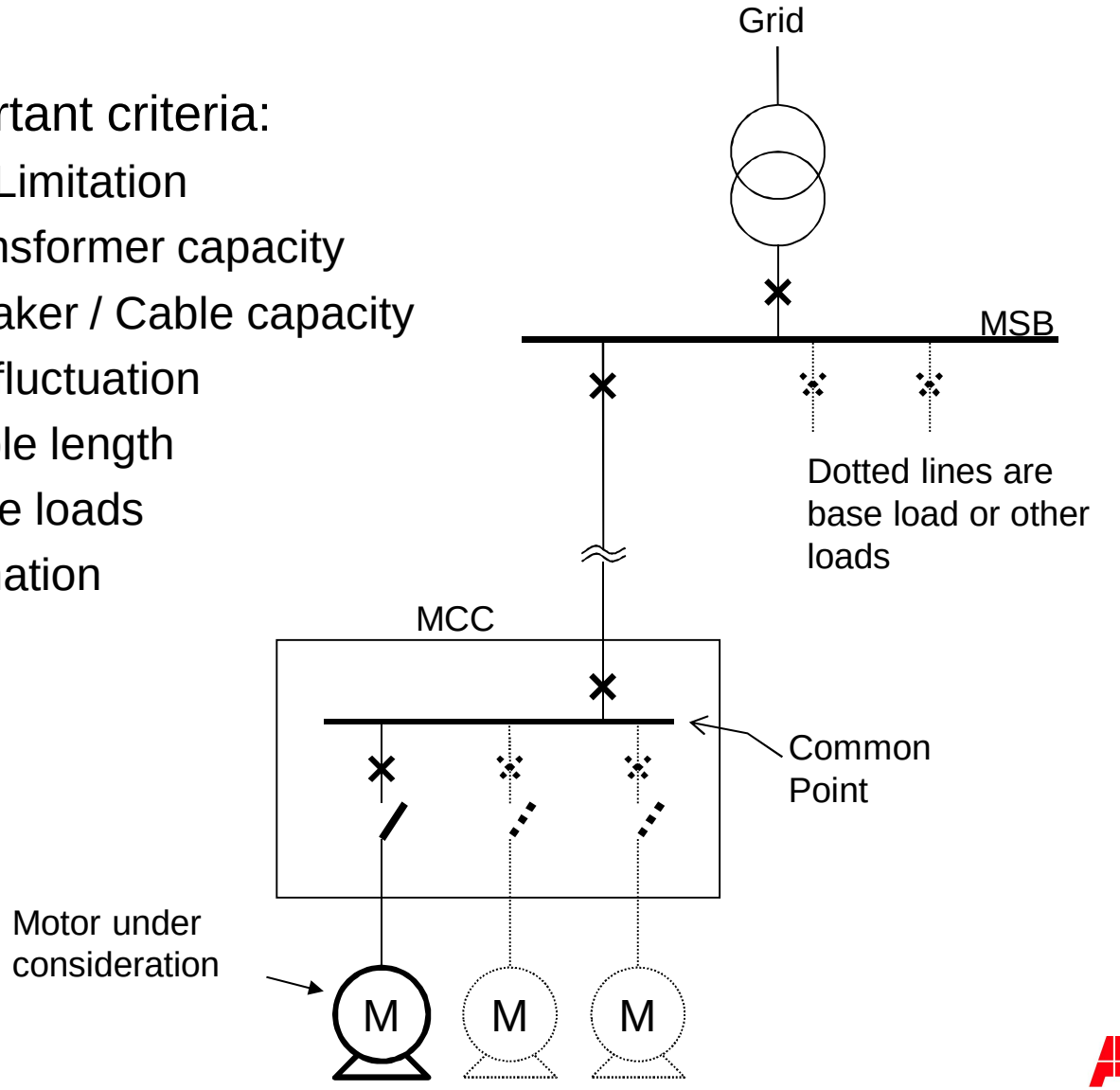
Motor Starter Appreciation
Considerations in Starter Selection

Motor Starter Appreciation
Elect. Consideration: Electrical system



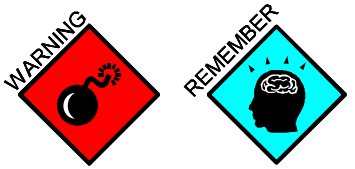
Three important criteria:

1. System Limitation
   - Transformer capacity
   - Breaker / Cable capacity
2. Voltage fluctuation
   - Cable length
   - Base loads
3. Co-ordination



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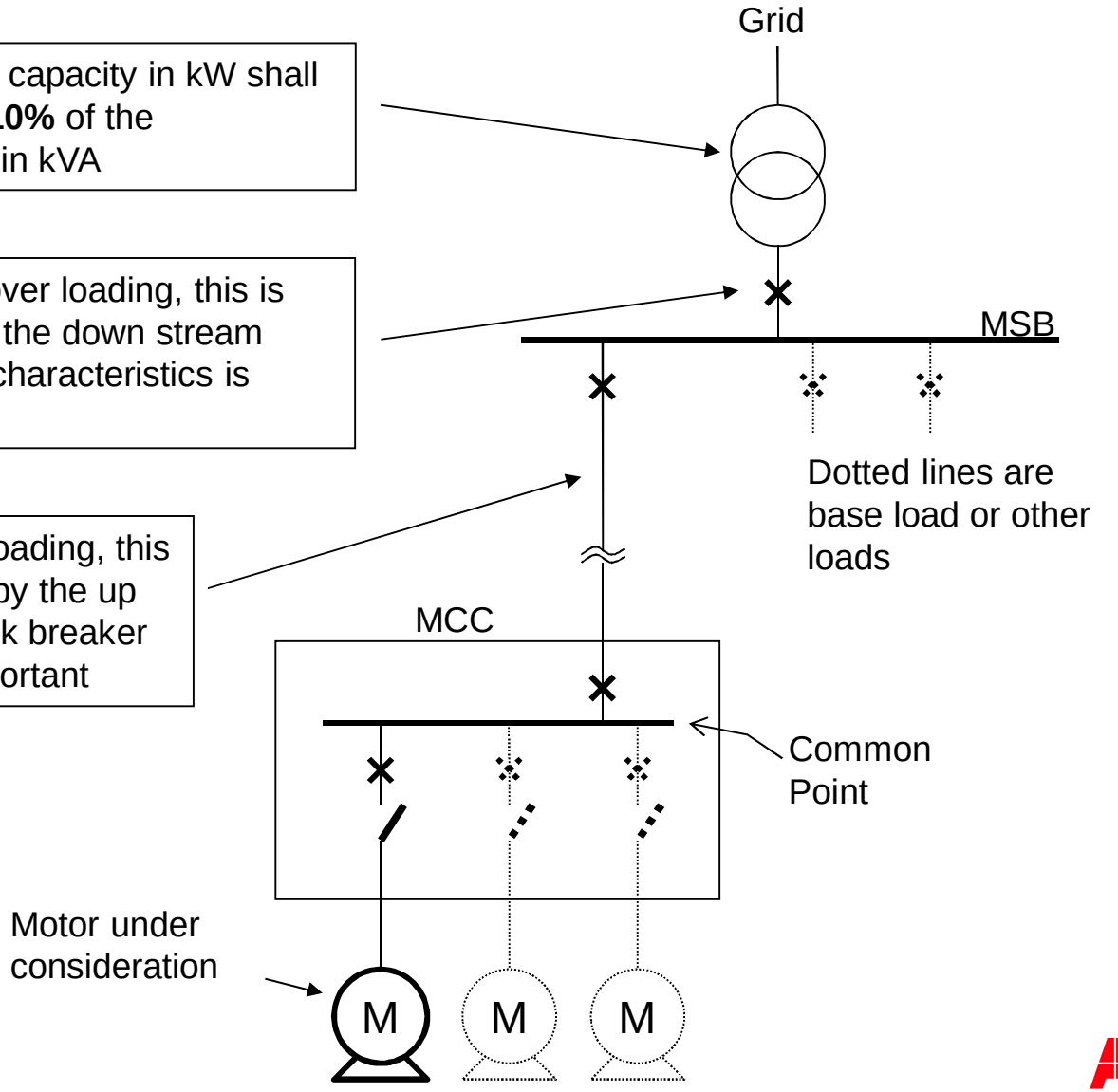
Motor Starter Appreciation
System limitation



For DOL starter, any motor capacity in kW shall **not** be greater than **10%** of the transformer capacity in kVA

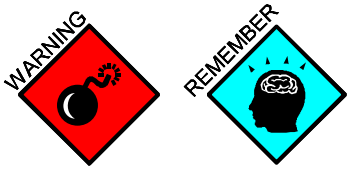
Prevent transformer from over loading, this is usually protecting by the down stream breaker, check both characteristics is important

Prevent cables from over loading, this is usually protecting by the up stream breaker, check breaker characteristics is important



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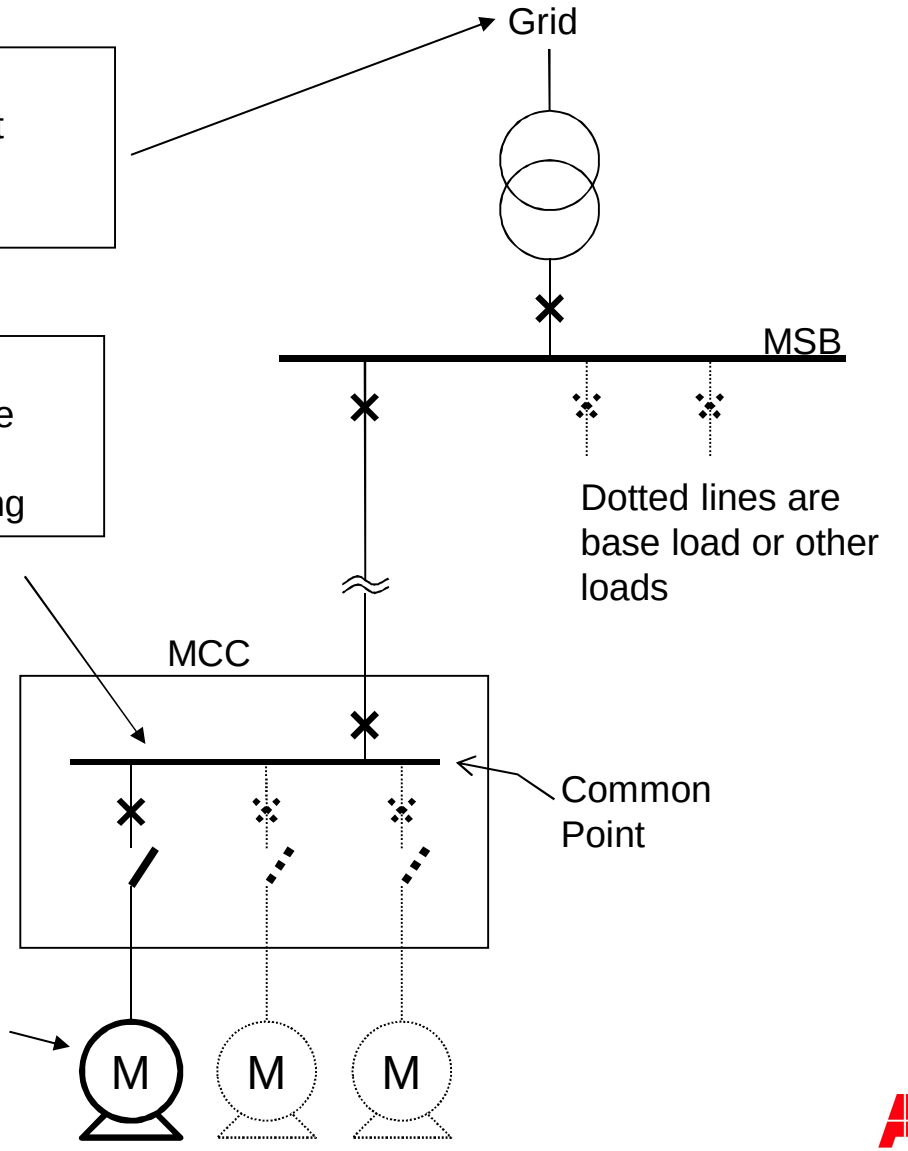
Motor Starter Appreciation
Voltage fluctuation



Rule of Thumb 1
Voltage drop at grid shall be within the limit specified by Power Grid (PG) (info can be found in PG Handbook)

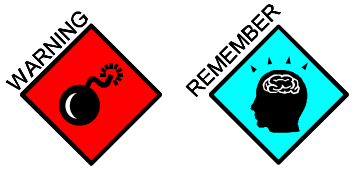
Rule of Thumb 2
Not more than **10%** of the additional voltage drop is acceptable at the common coupling point during the motor starting

Note: Common coupling point refers to the nearest point at the up stream of the starter that other loads are connected



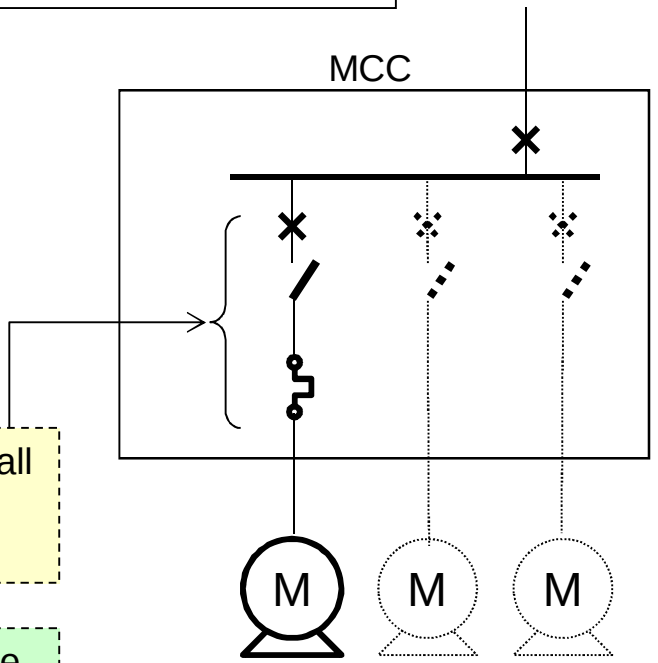
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Motor Starter Appreciation
Co-ordination



Two Types of co-ordination
1. Type 1 co-ordination – Safety
   Damage to component/s is/are acceptable but without occurrence of FIRE.
2. Type 2 co-ordination – Safety + reduction in down time
   Damage to component/s is/are not acceptable*

No co-ordination: High Risk
- Risk of FIRE, damage to property and causes harm to personal
- ARC flash/blast may occur, injury to personal
- Damage to components, increases down time

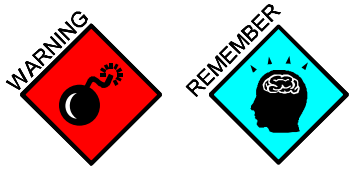


Note: The selection of all components in the motor starter shall be well co-ordinated
e.g. **circuit breaker, contactor, overload relay,** etc

* Slight welding of contact points are acceptable, provided the contact point can be separated and work as per normal without de-rating

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Motor Starter Appreciation
Co-ordination (cont'd)



8.2.5 Co-ordination with short-circuit protective devices

8.2.5.1 Performance under short-circuit conditions (rated conditional short-circuit current)

The rated conditional short-circuit current of contactors and starters backed up by short-circuit protective device(s) (SCPD(s)), combination starters, combination switching devices, protected starters and protected switching devices shall be verified by short-circuit tests as specified in 9.3.4. These tests are mandatory:

a) at the appropriate value of prospective current shown in Table 13 (test current "*r*"), and

b) at the rated conditional short-circuit current I_q, if higher than test current "*r*".

The rating of the SCPD shall be adequate for any given rated operational current, rated operational voltage and the corresponding utilization category.

Two types of co-ordination are permissible, "1" or "2". The test conditions for both are given in 9.3.4.2.1 and 9.3.4.2.2.

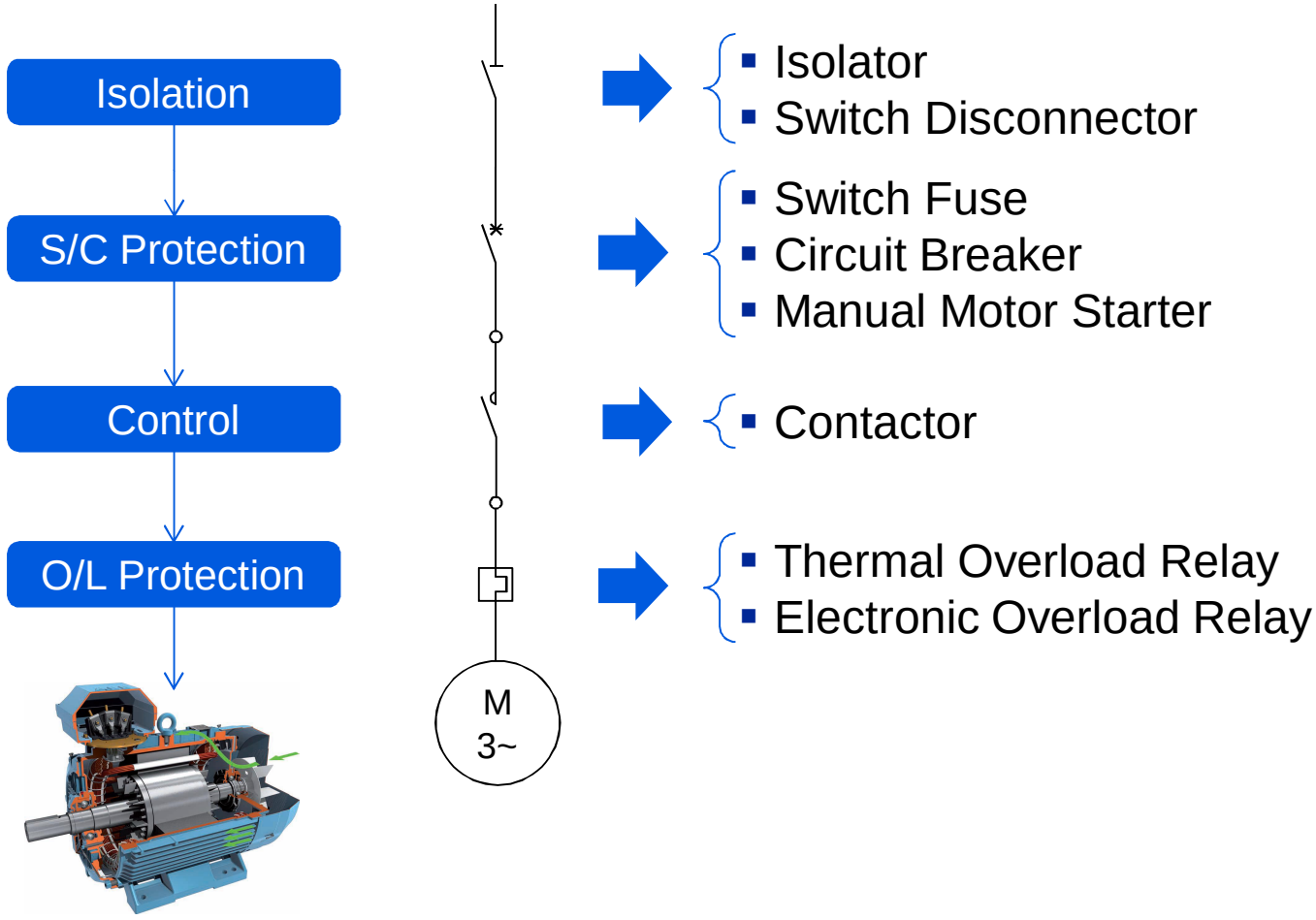
Type "1" co-ordination requires that, under short-circuit conditions, the contactor or starter shall cause no danger to persons or installation and may not be suitable for further service without repair and replacement of parts.

Type "2" co-ordination requires that, under short-circuit conditions, the contactor or starter shall cause no danger to persons or installation and shall be suitable for further use. The risk of contact welding is recognized, in which case the manufacturer shall indicate the measures to be taken as regards the maintenance of the equipment.

NOTE Use of an SCPD not in compliance with the manufacturer's recommendations may invalidate the co-ordination.

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Motor Starter Appreciation
Principal requirement in motor starters



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Motor Starter Appreciation
Isolation



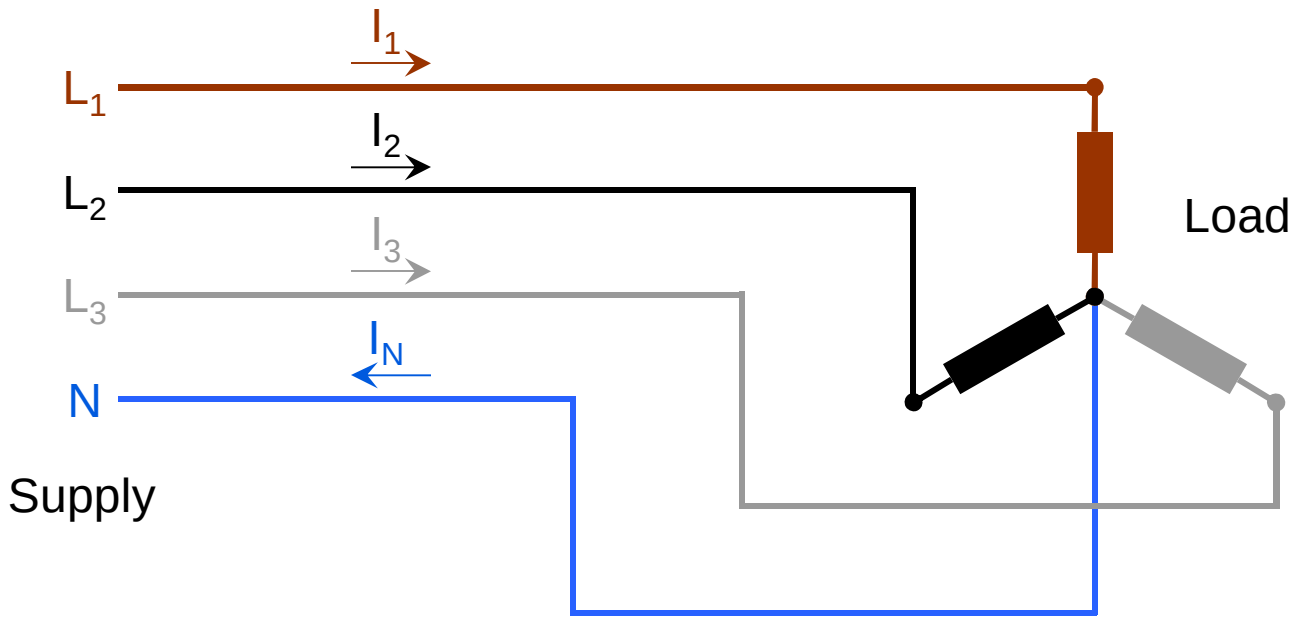
- What is Isolation?
  - Acc. to Longman Dict., “ when one group, person, or **thing** is separate from others”.
- Why is isolation required?
  - To separate the electrical (input) source from the motor starter → so that the engineers can carry out maintenance/troubleshooting on the motor starter w/o risk of electrocution.
- How is isolation achieved?
  - By means of load break switches (or switch disconnectors, different manufacturers name them differently, but they serve the same purpose).
- Does ABB sell switch disconnectors?
  - Sure do, approach your ABB sales rep. for selection and quotation.

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Motor Starter Appreciation
Short Circuit Protection



- What is a short-circuit?
  - A short-circuit occurs during a fault (bet. phases, phase-neutral etc.) where the current finds the shortest path to travel albeit it is not the intended path.

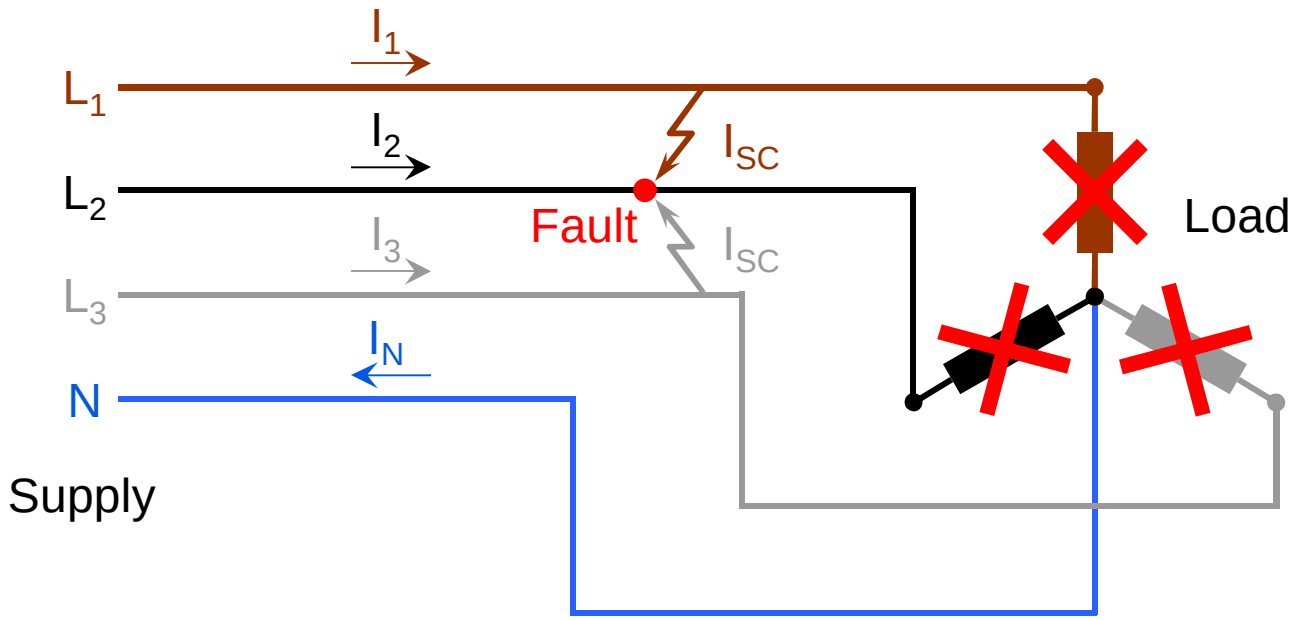


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Motor Starter Appreciation
Short Circuit Protection



- What is a short-circuit?
  - A short-circuit occurs during a fault (bet. phases, phase-neutral etc.) where the current finds the shortest path to travel albeit it is not the intended path.



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Motor Starter Appreciation
Short Circuit Protection (cont'd)



- What are the consequences of a short-circuit?
  - A short-circuit current, typically in kilo-amperes (depending on reactance of the system) passes through the fault, damaging the cables, components etc., if it is not cleared fast enough. Often short-circuits are accompanied by arc flashes.
- How do we protect our cables and components or motor starters then?
  - ABB offers short-circuit protection devices (SCPDs) such as ACB, MCCB, MCB and fuses for feeder or load protection. For motor protection, we can use Manual Motor Starters, refer to handouts.
  - Often in Asia, ACB, MCCB, MCB and Manual Motor Starters are often used as load break switches as well (to cut cost), because they serve the purpose of isolating the circuit in the OFF position.

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Motor Starter Appreciation
Control



- Why do we need control?
  - Control is needed to ON and OFF the power to the circuit or motor starter, by the user.
- What is used to control a circuit or motor starter?
  - Breakers are not designed to ON and OFF a circuit or motor starter so frequently, as they are designed for ~ 250,000 + open/close operations. → Contactors are designed for ~ 5 million mechanical open/close operations.
- How does a contactor achieve the control operation?
  - Contactors are electro-magnetic devices that energizes the coil and induces a magnetic field to pull in the core, in turn making the contacts.
  - As such, contactors require an auxiliary voltage, commonly known as control voltage, in the industry.

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Motor Starter Appreciation
Contactors

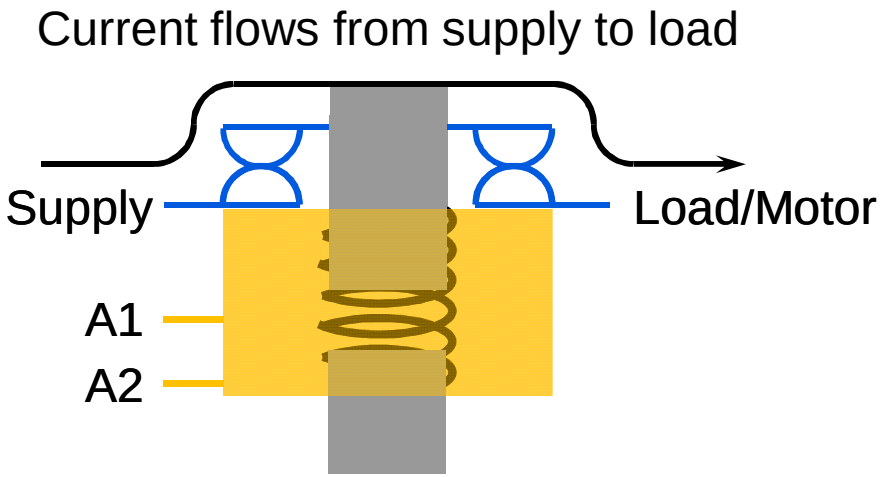


Factors affecting the right contactor for your application

- Operational voltage and current
- Utilization category (affects electrical lifespan of contacts)
- Coil voltage

Construction of electro-mechanical contactors

- Sets of contacts
- Spring
- Coil
- Iron core



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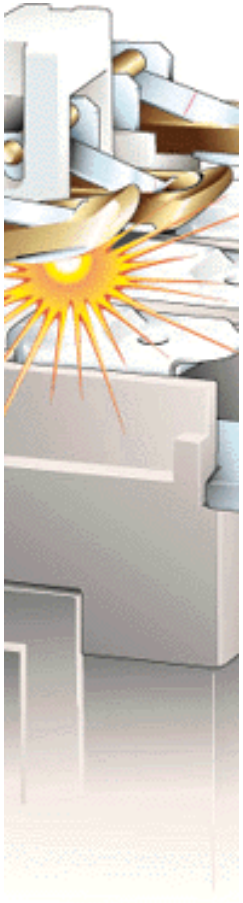
Motor Starter Appreciation
Contactors



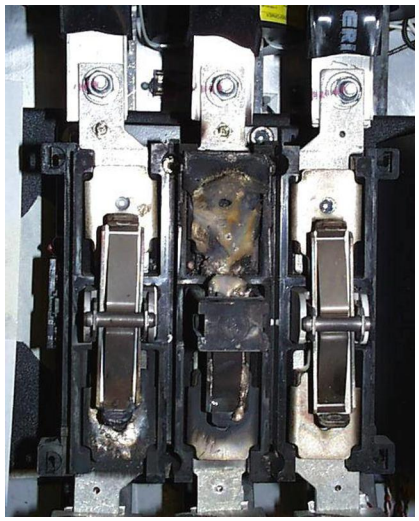


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Motor Starter Appreciation
Welded contacts



- From the clip, it is realized that the contacts are experiencing the brunt of breaking/making the motor current
- Often the contactor gets welded due to:
  - Insufficient coil voltage
    - Poor system stability
    - Voltage drop in cables
  - High inrush exceeding making capacity of contactors
  - Short-circuit





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Motor Starter Appreciation
Overload Protection



- Why do we need overload protection for motors?
  - An induction motor is a device that converts electrical energy (supply) to mechanical energy (work), it does not have any intelligence. Hence, when the demand for mechanical energy goes higher, it will request for more electrical supply, w/o knowing its limits, its windings break down as a result due to overheating.
  - Therefore, motors have a temperature rating!
- What is the principle behind overload relays?
  - Thermal overload relays (TOR) uses bimetallic strips to detect if the drawn current has exceeded its threshold and breaks the contacts. Electronic overload relays (EOR) uses CTs to detect the current drawn by the motor, hence EORs **CANNOT** be used on d.c. circuits!

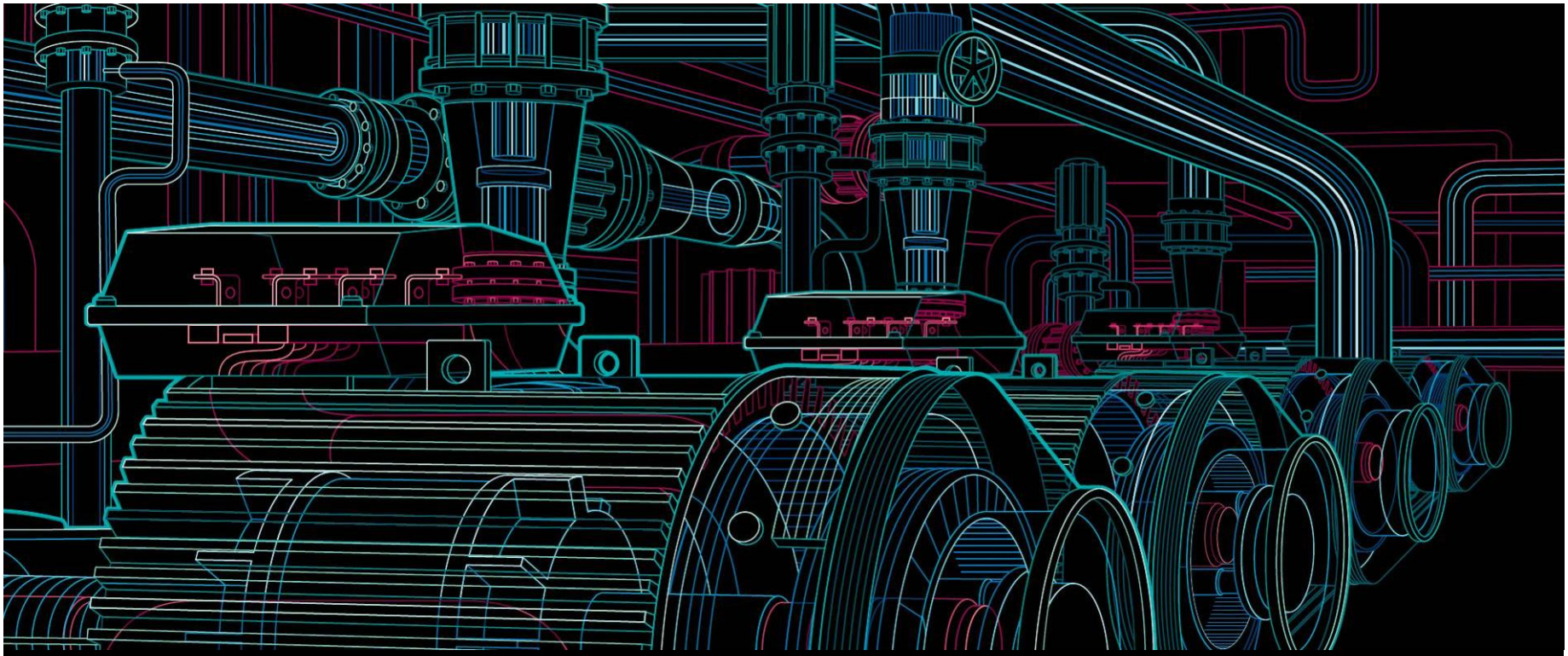
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Motor Starter Appreciation
Overload Protection (cont'd)



- What is temperature compensation for overload relays?
  - ABB's TORs have temperature compensation, i.e. if the ambient temperature is too hot, the bimetallic strips in the TOR will give a narrower margin for the current requirement from the motor.

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Motor Starter Appreciation

The Various Methods of Motor Starting

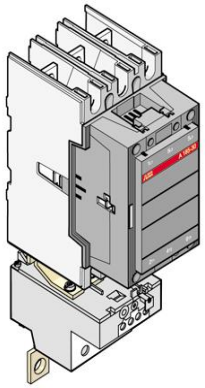
Motor Starter Appreciation
Types of motor starters

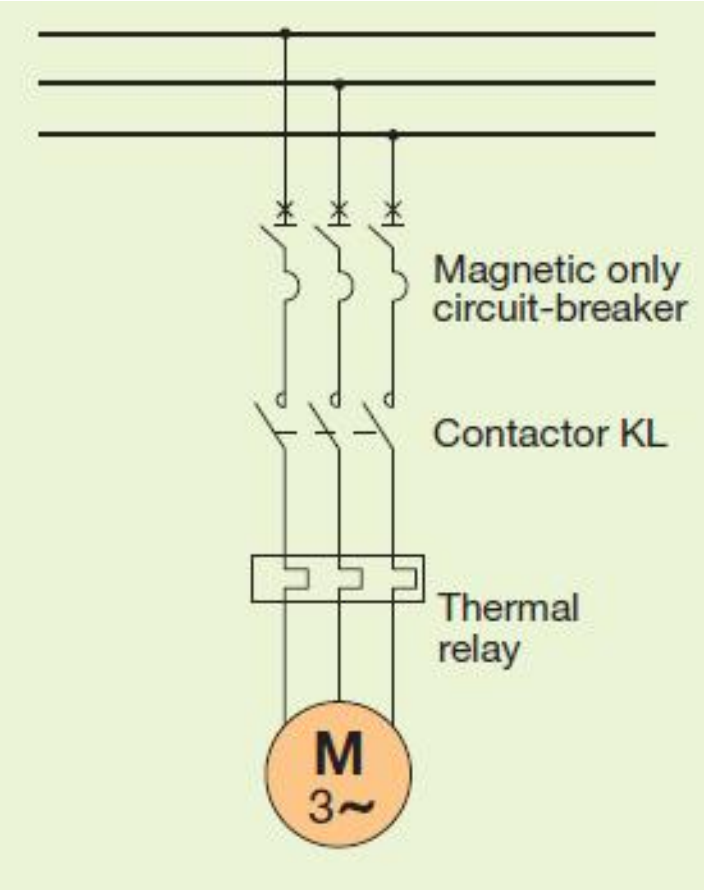
- Full-voltage starters
  - Direct-on-line starters
  - Reversing starters
  - Rotor resistance starters

- Reduced voltage starters
  - Star-delta starters
  - Star-delta starters (closed transition)
  - Auto-transformer starters
  - Soft-starters
  - Primary resistance starters
  - Part winding starters

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Motor Starter Appreciation
Direct-on-line starters



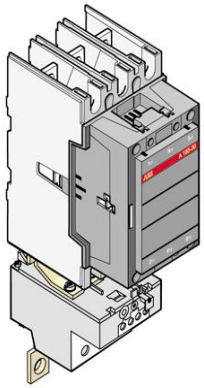


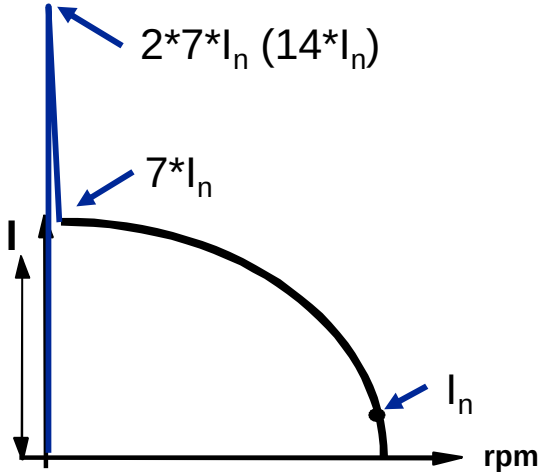
- High starting current
- High starting torque (mechanical wear)
- Shortest possible starting time
- Always direct stop
- Cheap solution

Guideline: ≤ 2.2kW motor

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Motor Starter Appreciation
Direct-on-line starters







- High inrush current
- Magnetization peak
- When using MCCB's this will force up the setting in order to avoid tripping during start
  - Can effect the size of the cables = higher cost
- Very high starting torque
- Heavy wear & tear on couplings, gearboxes etc

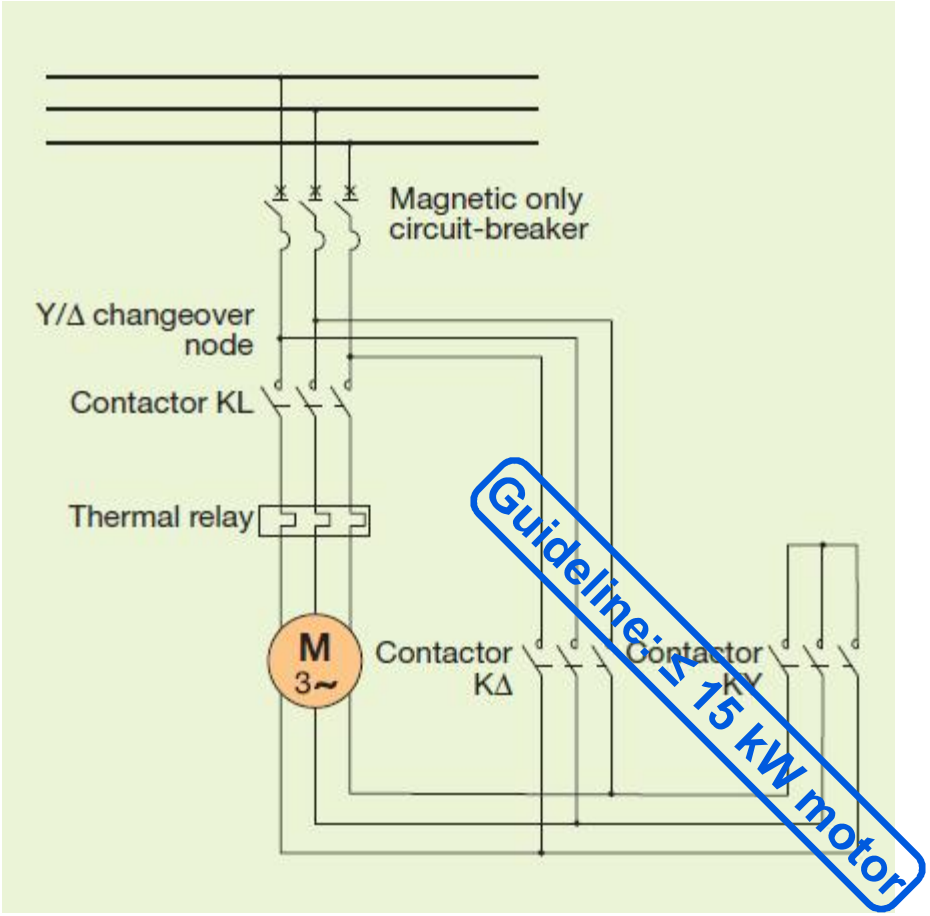
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Motor Starter Appreciation
Direct-on-line starters



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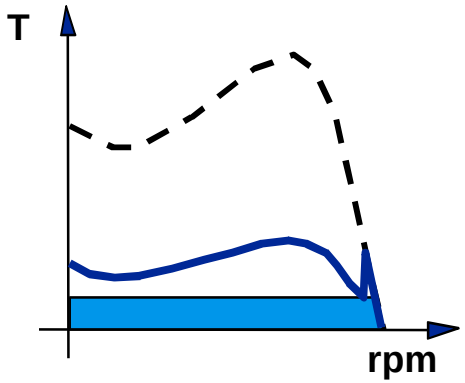
Motor Starter Appreciation
Star-delta starters (Y/D starters)



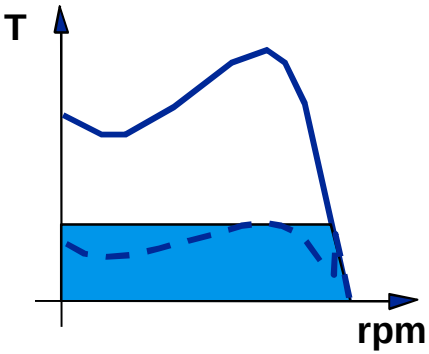
- Low starting current
  (only at successful start)
- Transmission peaks
  at loaded start
- Low starting torque
  (often too low)
- Long starting time
- Always direct stop
- Many devices – much wiring
- Double cables to the motor

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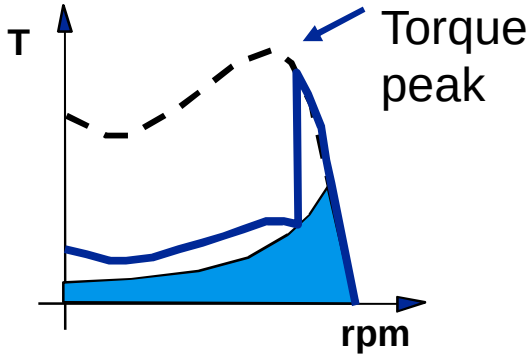
Motor Starter Appreciation
Star-delta starters (Y/D starters)



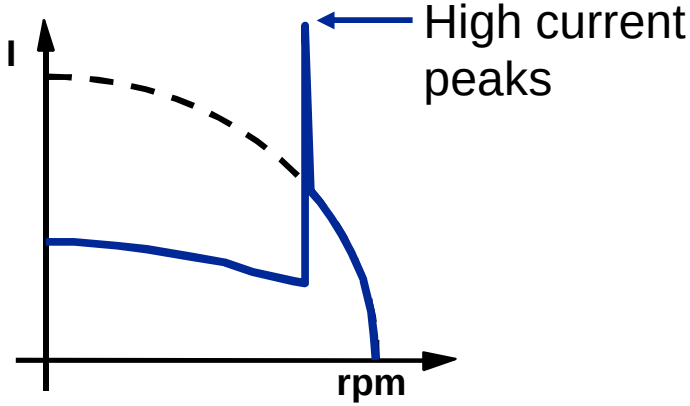
Low load

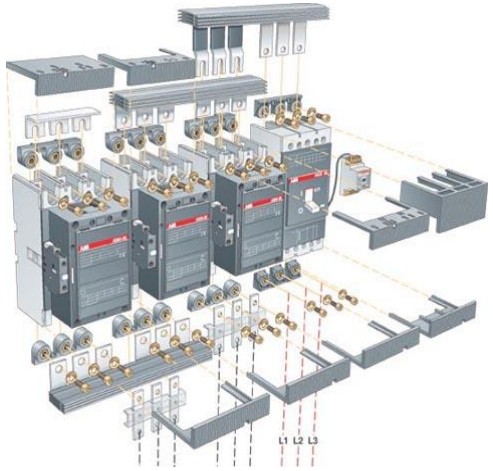


High load



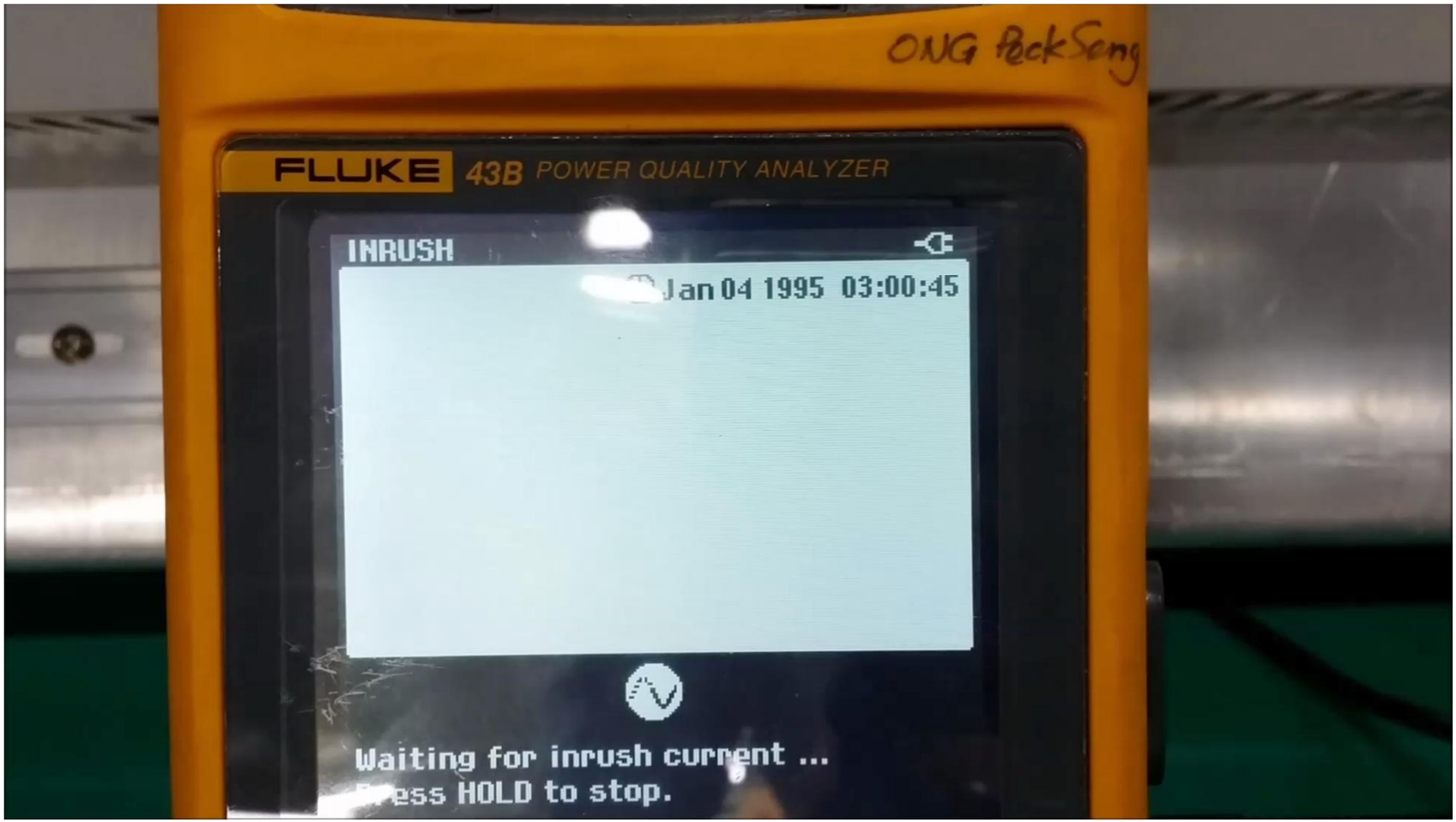
Medium load





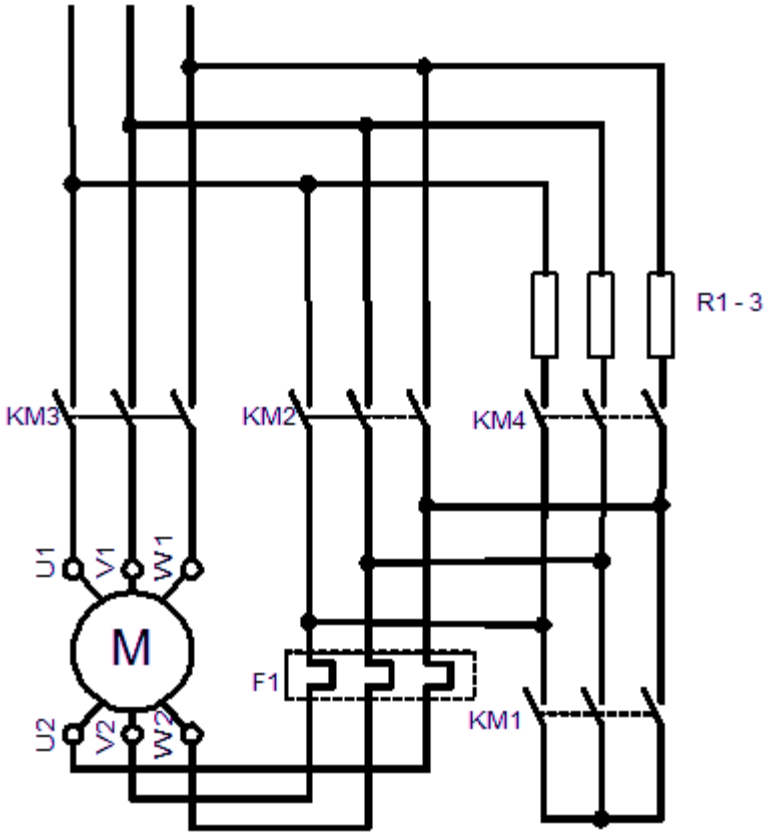
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Motor Starter Appreciation
Star-delta starters (Y/D starters)



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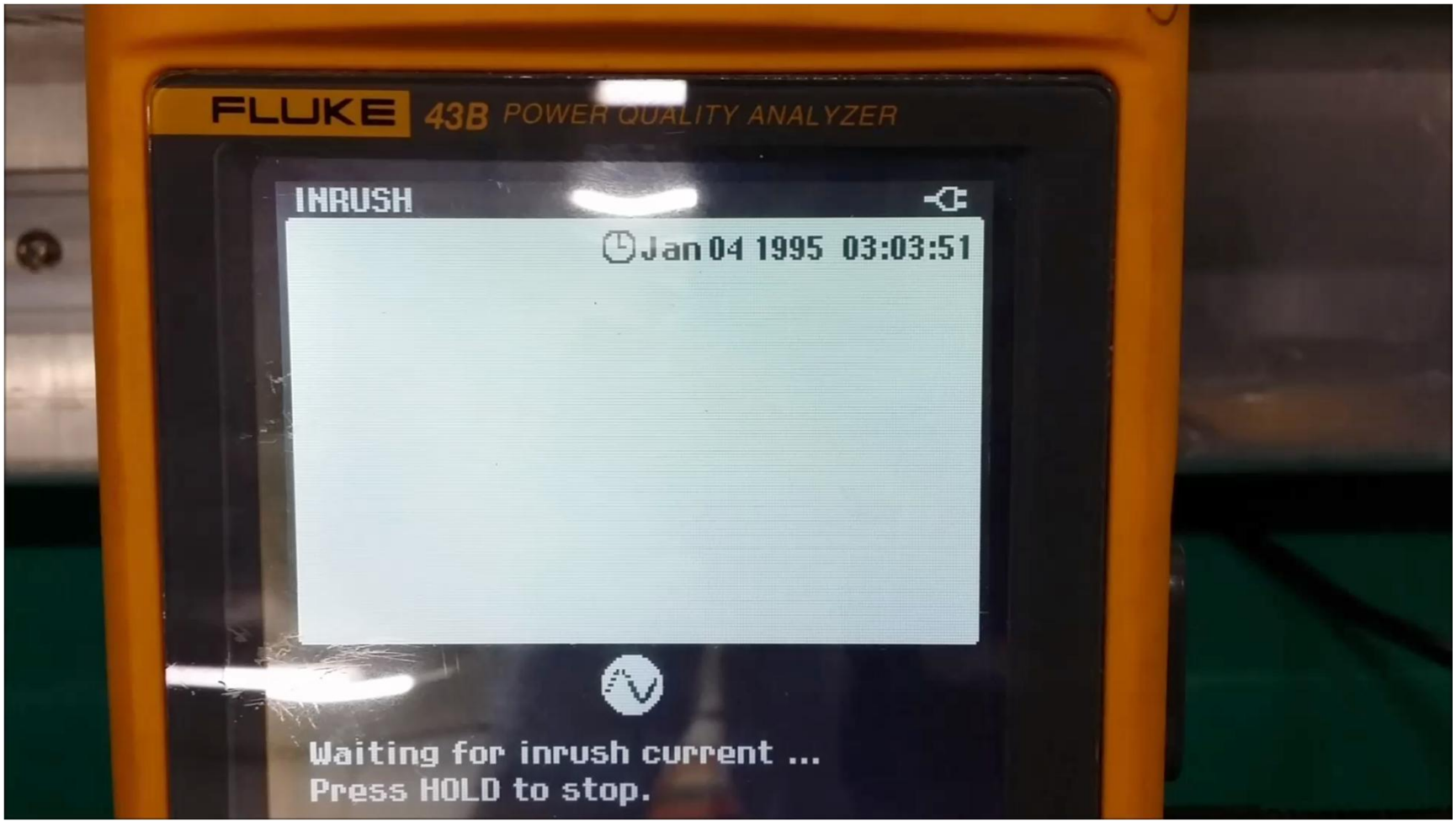
Motor Starter Appreciation
Star-delta starters (closed transition)



- Same as open transition Y/D starter
- Reduced transition peak current
- Smoother transition from star to delta connection
- Additional components required (resistor)
- Complicated design
- Higher maintenance compared to Open transition Y/D starter

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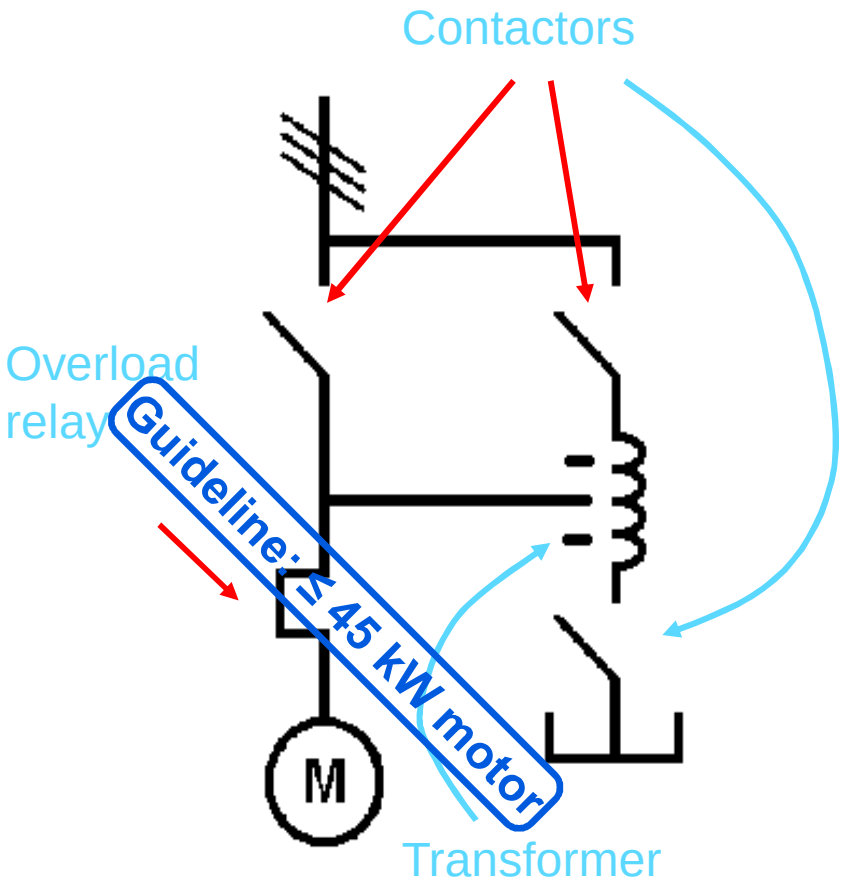
Motor Starter Appreciation
Star-delta starters (closed transition)



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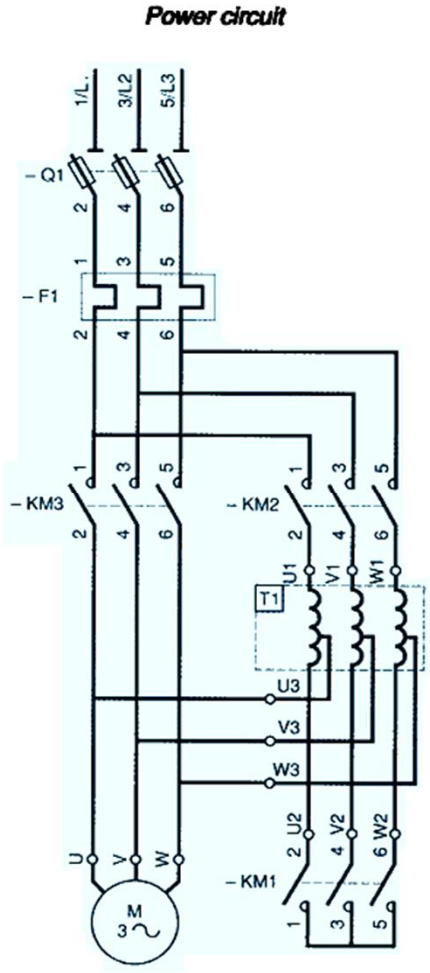
Motor Starter Appreciation
Auto-transformer starters

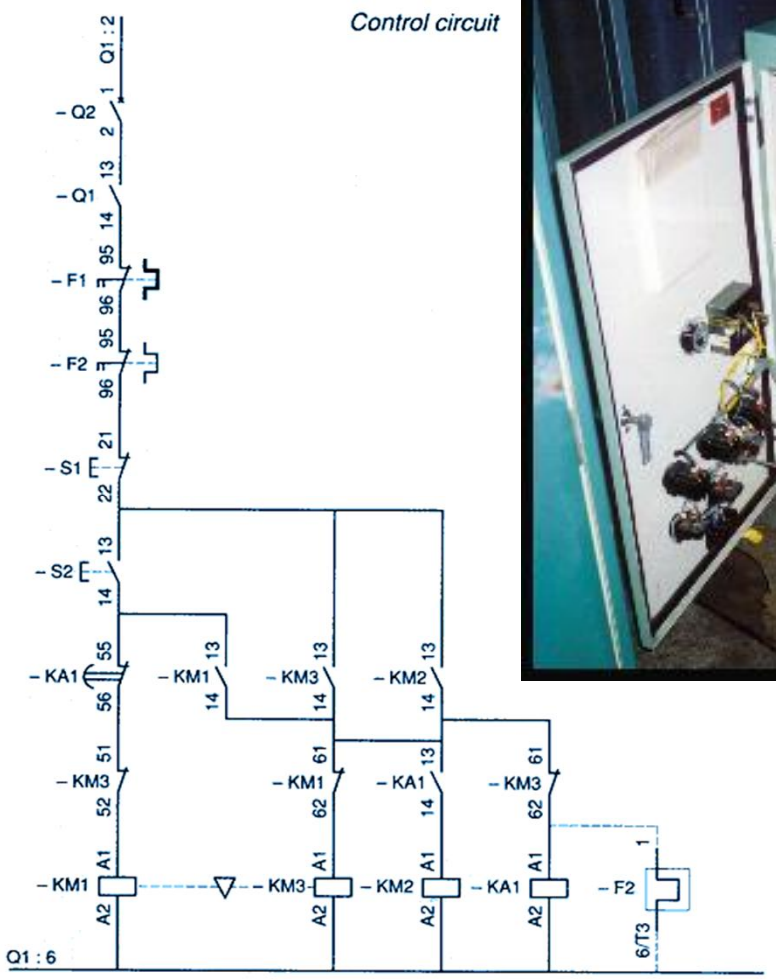
- Three different tap selections available
- Reduced starting current, between 25 to 65% of the DOL starting current
- Closed transition
- Large size
- Heat generated by autotransformer
- Limited number of starting per hour (2x)
- Expensive, between Y/D and softstarter
- Could be replace by soft-starter



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Motor Starter Appreciation
Auto-transformer starters
Typical Circuit Diagram

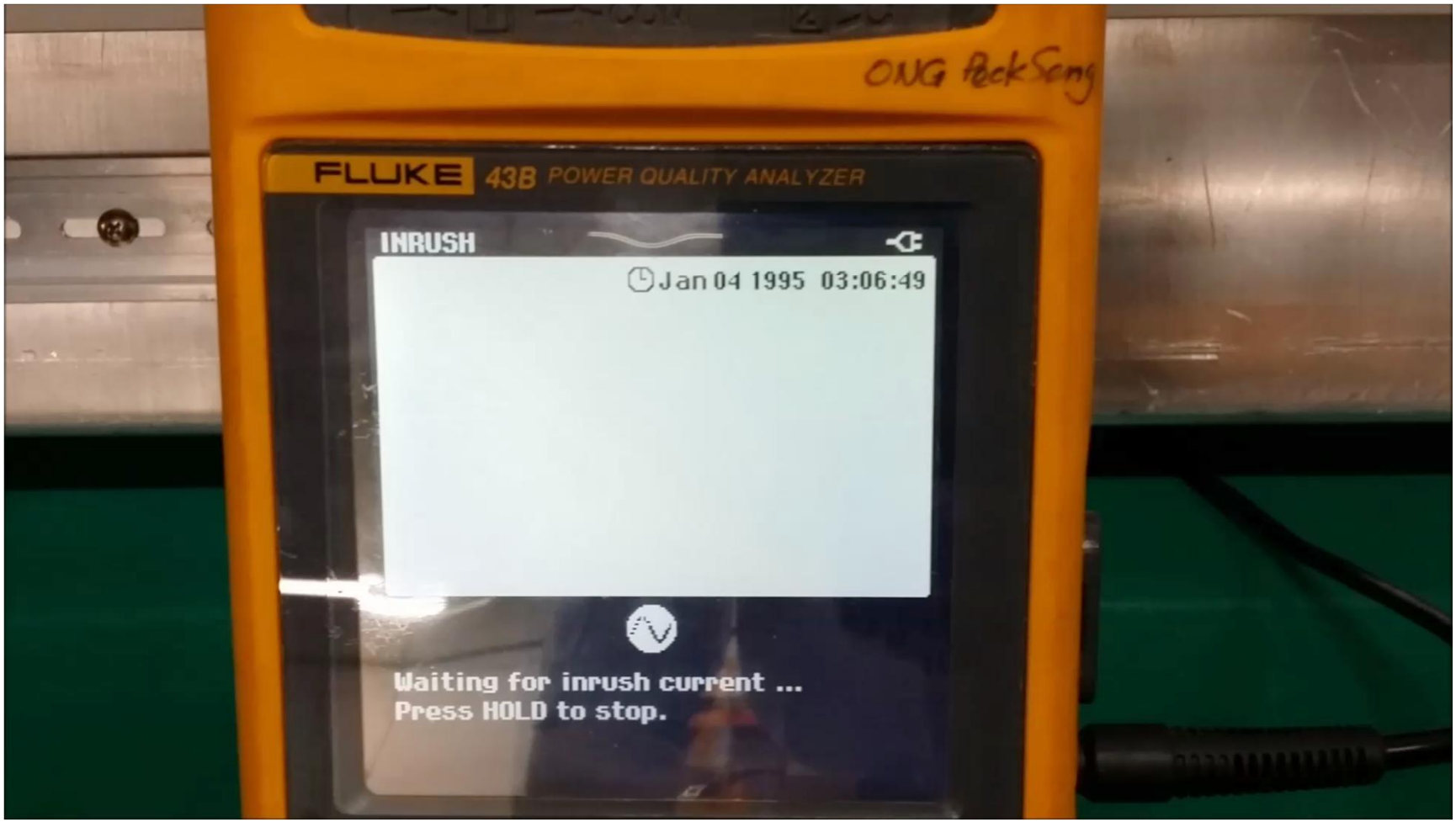






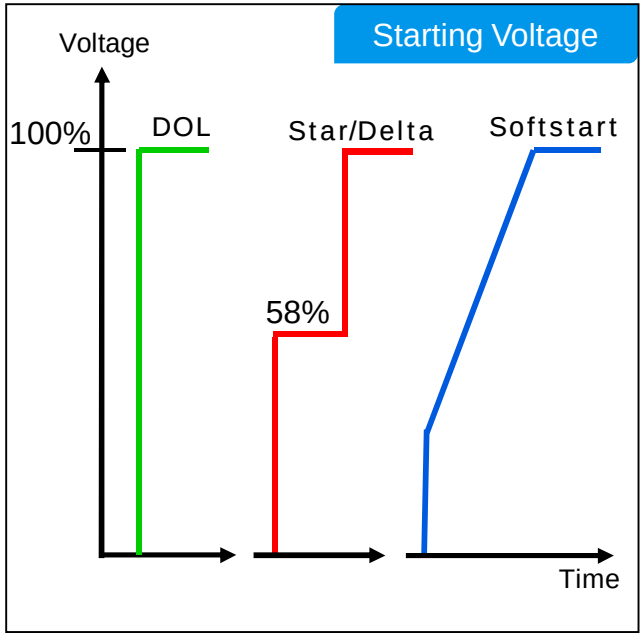
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Motor Starter Appreciation
Auto-transformer starters

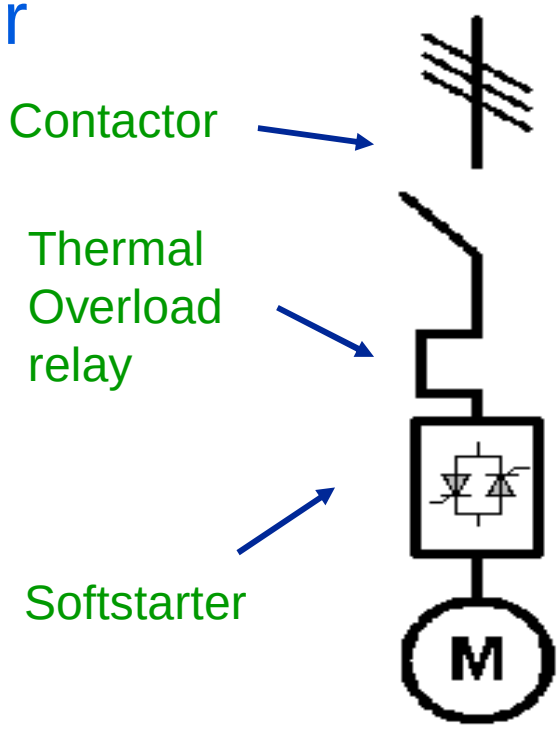


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Motor Starter Appreciation
Basic functionality of softstarter



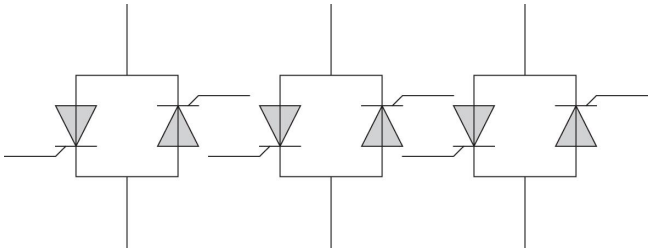
Example

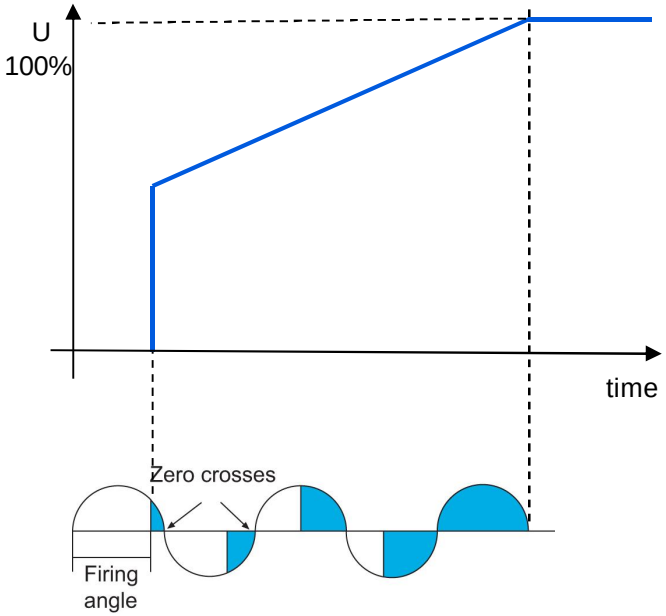


Used to start and stop electrical asynchronous motors
Used for constant speed applications
The softstarter ramps up/down the motor voltage to achieve a soft start/stop.
Reduces voltage drops in the network

Reduces mechanical wear
Adjustable starting current
Correct starting torque
Medium long starting time

Motor Starter Appreciation
Principal function of softstarter

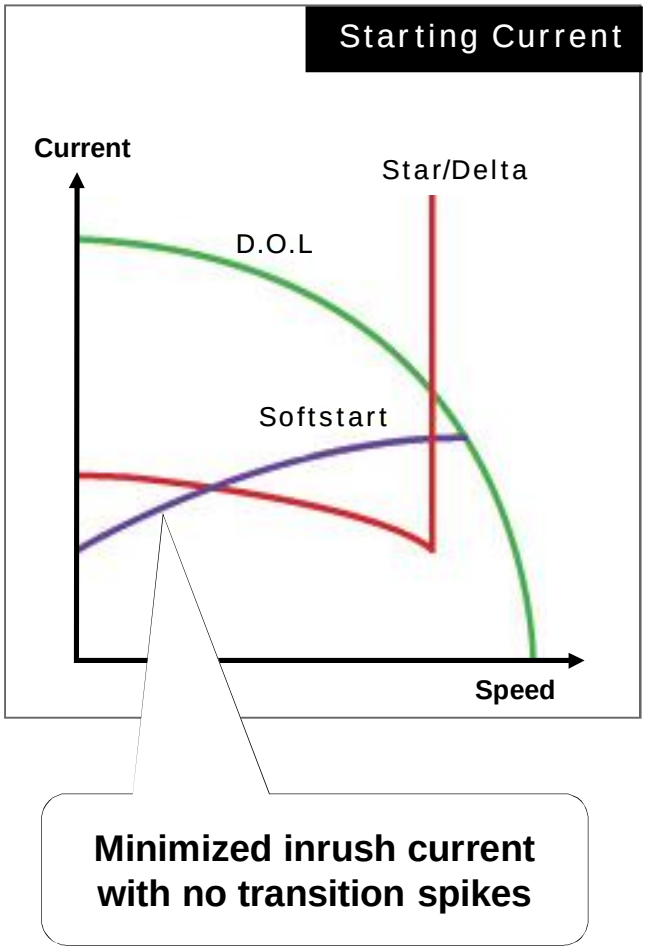




- The core of the softstarter are the thyristors
- The thyristors come in three pairs: one positive and one negative for each phase
- The voltage ramp shows the RMS value (time average over each period)
- The smooth voltage increase is achieved by modify the outgoing sinus signal by trigger the thyristors in a particalur sequence
- The larger the blue area, the higher voltage
- If half of the period is filled, 50% of max voltage is let through to the motor

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Motor Starter Appreciation
Benefits for the electrical network with softstarter

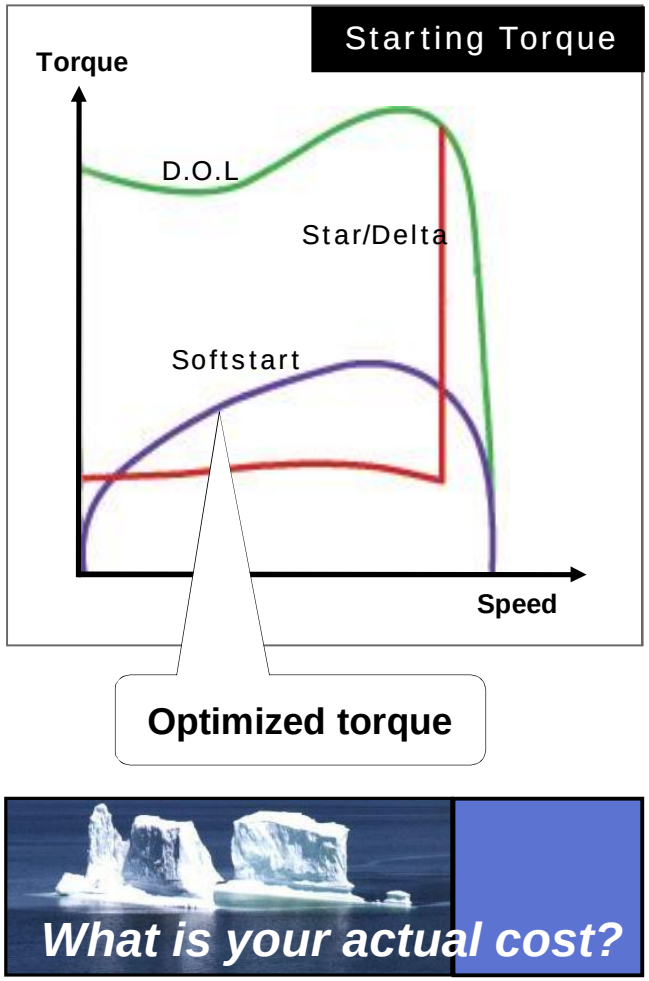


Benefits for the electrical network

Reduces voltage drops on networks
Minimizes starting currents
Eliminates current spikes
Allows optimization of cabling

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Motor Starter Appreciation
Mechanical benefits with softstarter



Mechanical benefits

Minimizes stress on transmissions like gearboxes, belts and bearings

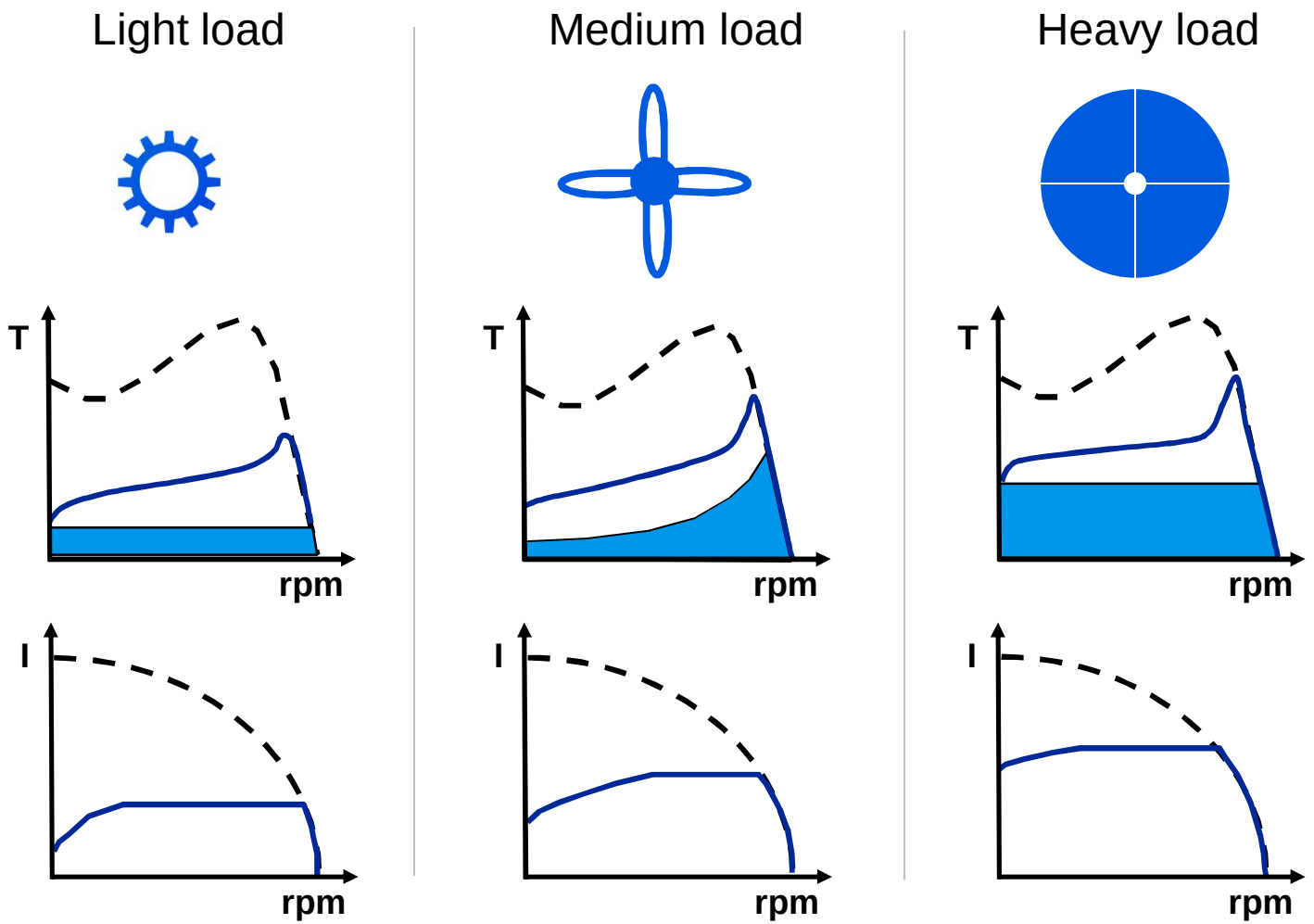
Reduced water hammering

Minimizes maintenance cost

Reduces down-time

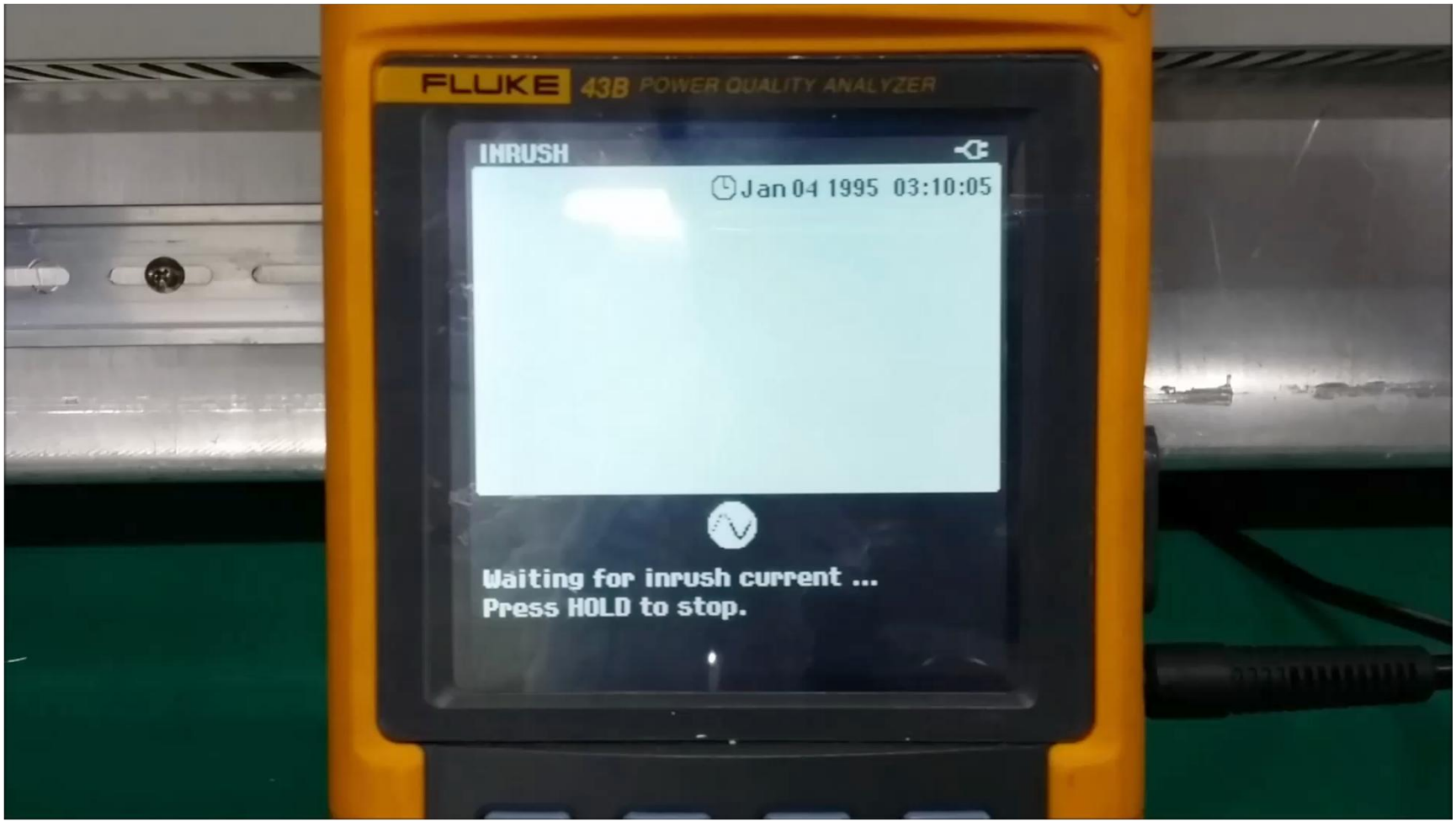
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Motor Starter Appreciation
Softstarter starting with different loads



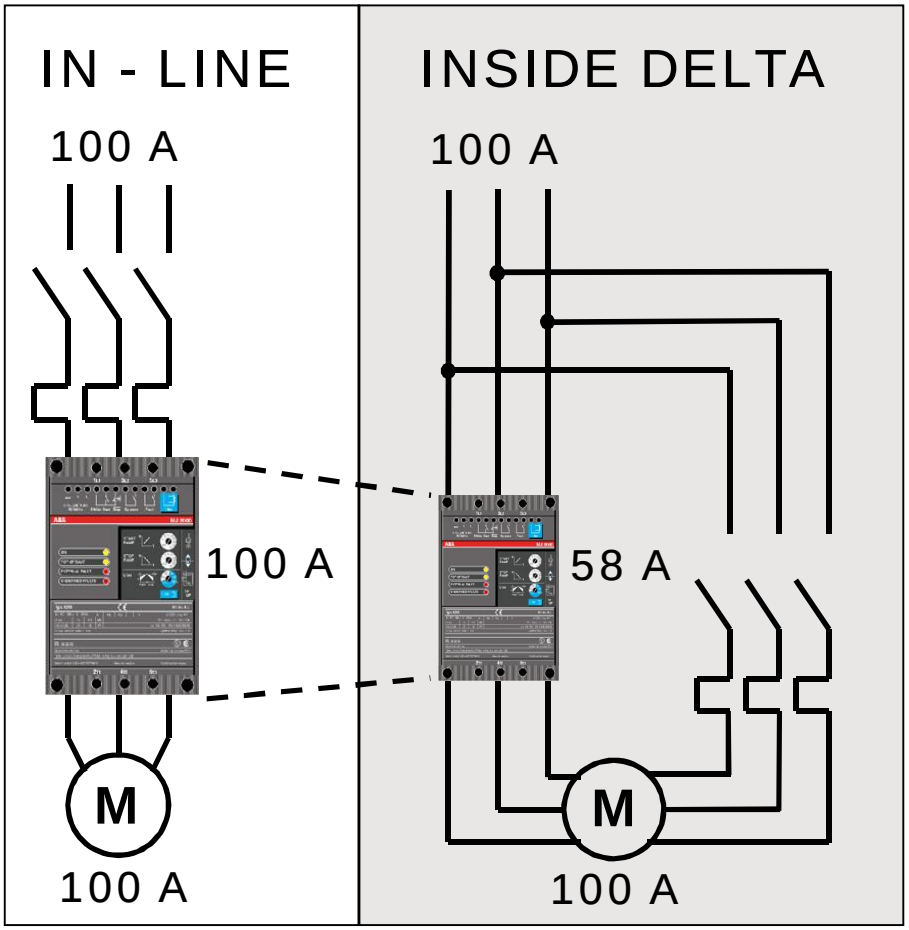
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Motor Starter Appreciation
Softstarter starting



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Motor Starter Appreciation
Softstarter connection



Three phase controlled softstarter can be connected both in line or inside delta

Down-sizing possible with inside delta (softstarter, OL-relay & line contactor)

Easy to replace star-delta starter

All functionality is the same

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Motor Starter Appreciation
By-pass contactor in softstarter

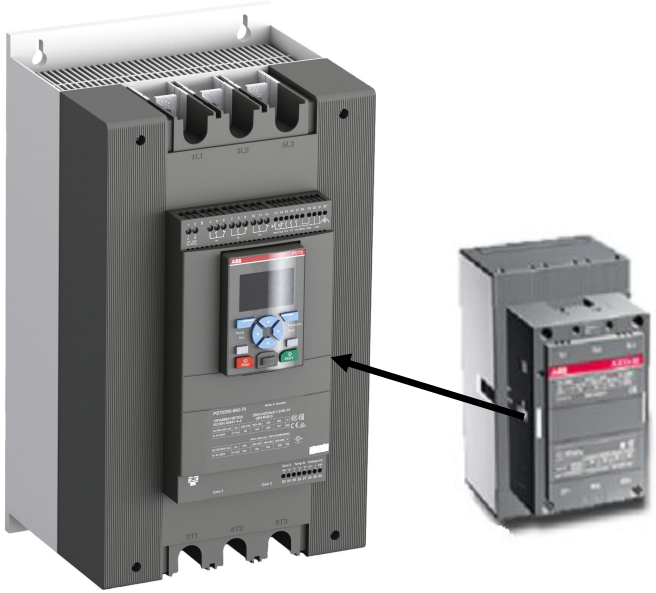


Why to use by-pass contactor?

Energy saving

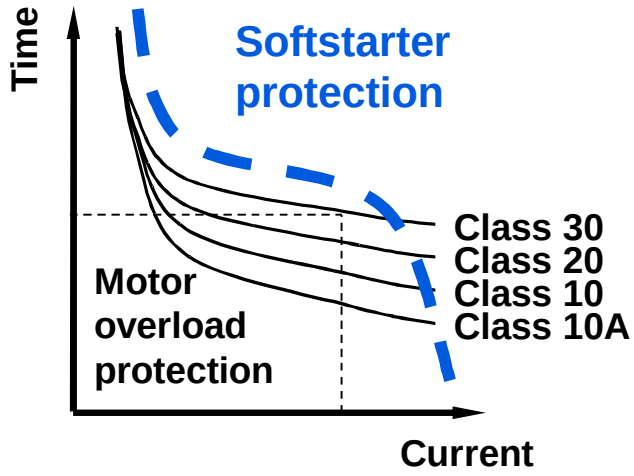
Reduced need for cooling

More starts per hour



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Motor Starter Appreciation
Advanced motor protection in softstarter



Motor protection
4 trip classes: 10A,10, 20 & 30
Dual overload
Locked rotor protection
Under load protection
PTC protection

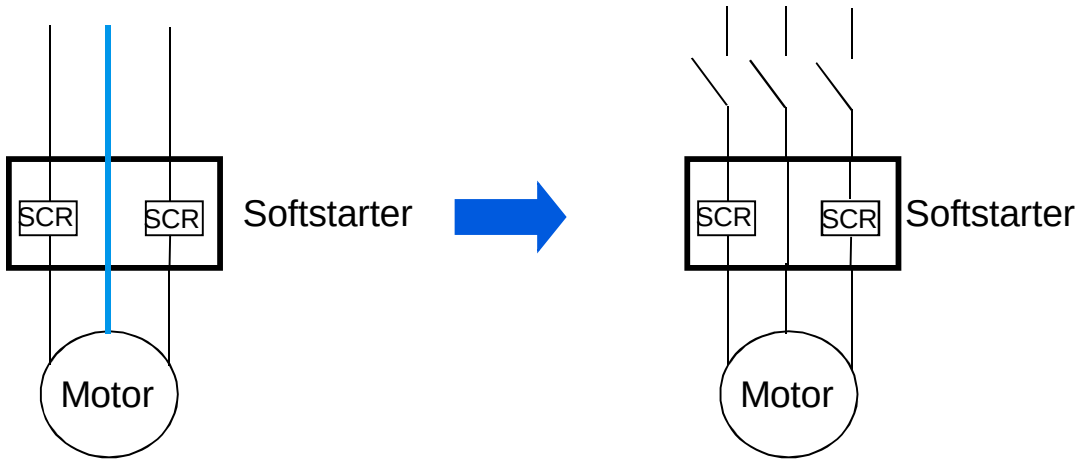
Phase Monitoring
Phase imbalance protection
Phase reversal protection

Softstarter protection
Thyristor protection
High current protection

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Motor Starter Appreciation
Voltage on motor when stopped

Even when stopped, there will be a voltage on the motor
This will not start the motor and it will not heat up the motor (compare with inside delta)
Even with a 3-phase controlled softstarter, the softstarter should not be used for isolation.
Semiconductors does not replace air isolation.
Recommended solution is to use a line contactor. This is recommended also for 3-phase controlled softstarters.



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Motor Starter Appreciation
Starters comparison

Characteristic	DOL	S/D	Auto Trans	Softstarter
Starting time	Fastest	Slow	Slow	Slow
Starting torque	Highest	Low	Medium	Medium (settable)
Inrush current	Highest	Medium (high transitional spike if open transition)	Medium	Medium (settable)
Connections to motor	3	6	3	3/6 (depends on connection type)
Parameter setting	No	Timer	Timer, Auto trans tapping	Yes
Soft stop	No	No	No	Yes
Protection	Separate component	Separate component	Separate component	In-built for certain models

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