Motors, Motor Circuits and Controllers

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Two major components in motor control

POWER CIRCUITS:

- IT SHOWS THE WIRING OF THE MOTOR DIRECTLY TO THE LINE
- HIGHER VOLTAGE (1 OF 3-PHASE)
- LARGER SIZE OF CONDUCTOR

CONTROL CIRCUITS:

- IT CONTROLS THE MOTOR TO STOP OR RUN, FORWARD OR REVERSE ETC.
- LOWER VOLTAGE, USUALLY 1-PHASE
- SMALLER SIZE OF CONDUCTORS

Motor Control Installation Considerations

ELECTRICAL SERVICES –ESTABLISH WHETHER THE SERVICE IS DIRECT (DC) OR ALTERNATING CURRENT (AC). IF AC, DETERMINE THE FREQUENCY AND NUMBER OF PHASES.

MOTOR – THE MOTOR SHOULD MATCH TO THE ELECTRICAL SERVICES, OTHER CONSIDERATION ARE THE RATING(HP), SPEED-TORQUE CHARACTERISTICS, FULL-LOAD CURRENT(FLC), SERVICE FACTOR(SF), TIME RATING(DUTY), AND OTHER PERTINENT DATA AS SHOWN IN THE MOTOR NAMEPLATE-MUST BE USED.

OPERATING CHARACTERISTICS OF THE CONTROLLERS - THE FUNDAMENTAL TASKS OF THE MOTOR CONTROLLER ARE TO START AND STOP THE MOTOR AND TO PROTECT THE MOTOR AS WELL AS THE OPERATOR. THE CONTROLLER MAY ALSO BE CALLED UPON SUPPLEMENTARY FUNCTIONS SUCH AS REVERSING, JOGGING, OR ITCHING AT SEVERAL SPEED ETC.

ENVIRONMENT – THE MOTOR AND THE CONTROLLER IN CERTAIN APPLICATION MUST ALSO BE PROTECTED FROM A VARIETY OF ENVIRONMENTAL CONDITION WHICH MAY INCLUDE WATER,RAIN, DIRT, OIL, COOLANT ETC.

ELECTRICAL CODE AND STANDARDS- MOTOR CONTROL IS DESIGNED TO MEET THE PROVISION OF PHILIPPINE ELECTRICAL CODE (PEC)

Purpose of Controller

STARTING METHODS - USE TO START THE MOTOR IN GRADUAL SO AS TO PROTECT THE MACHINE

STOPPING- IT ASSIST THE STOPPING ACTION BY RETARDING CENTRIFUGAL MOTION OF MACHINE

REVERSING – IT CHANGES THE ROTATION OF THE MOTOR IF REQUIRED IN THE OPERATION

RUNNING – IT MAINTAIN THE DESIRED SPEED AND TORQUE WHILE PROTECTING THE MOTOR FROM ANY DANGER.

SPEED CONTROL – ADJUST THE DESIRED SPEED REQUIRED BY THE LOAD

POSITION CONTROL – POSITION THE END SHAFT ON THE DESIRED LOCATION.

Conventional Starting Method

Electro-mechanical Method

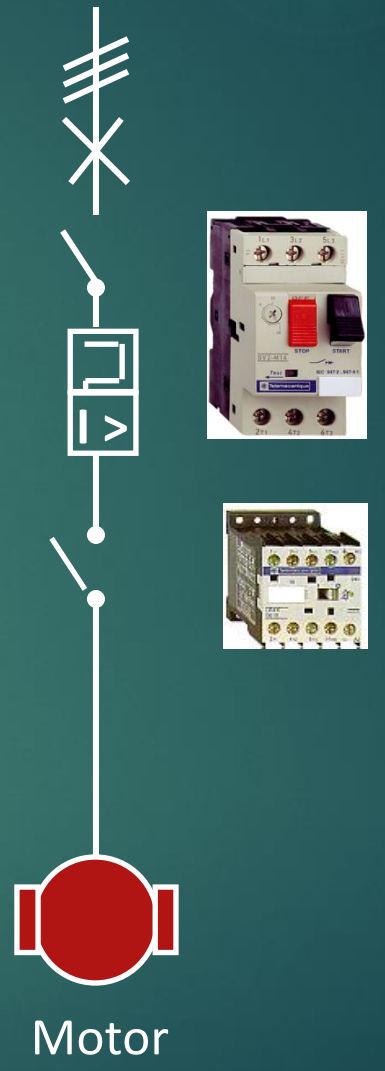
Direct Online
Wye-Delta Starting
Auto Transformer
Impedance of Resistance Starting Method

Electronics Method

Electronic Motor Soft starter
Variable Frequency Drive

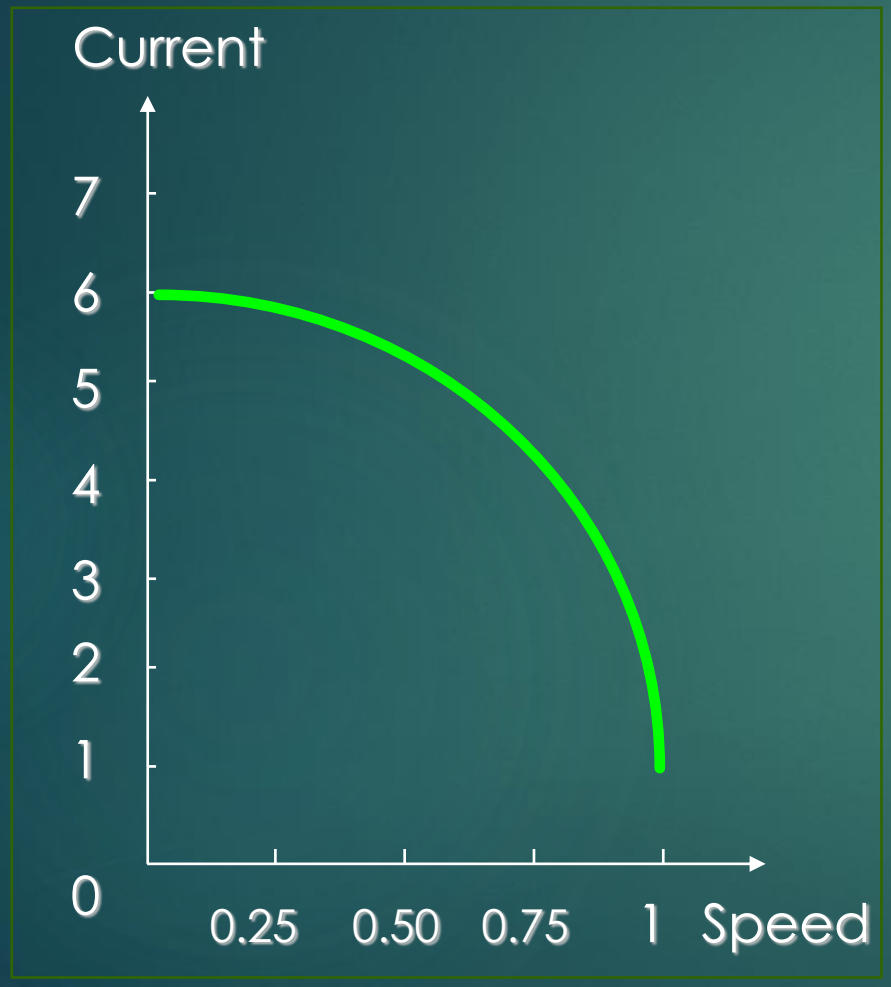
Direct On Line Starter

- ***Starting Current:***
  - *4 to 8 times rated current*
- ***Starting torque:***
  - *0.5 to 1.5 times rated torque*
- ***Utilisation criteria****:*
  - *3-terminal motor, low to medium power*
  - *starting on load*
  - *high starting current peak and voltage drop*
  - *simple equipment*
- ***No parameter adjustment***

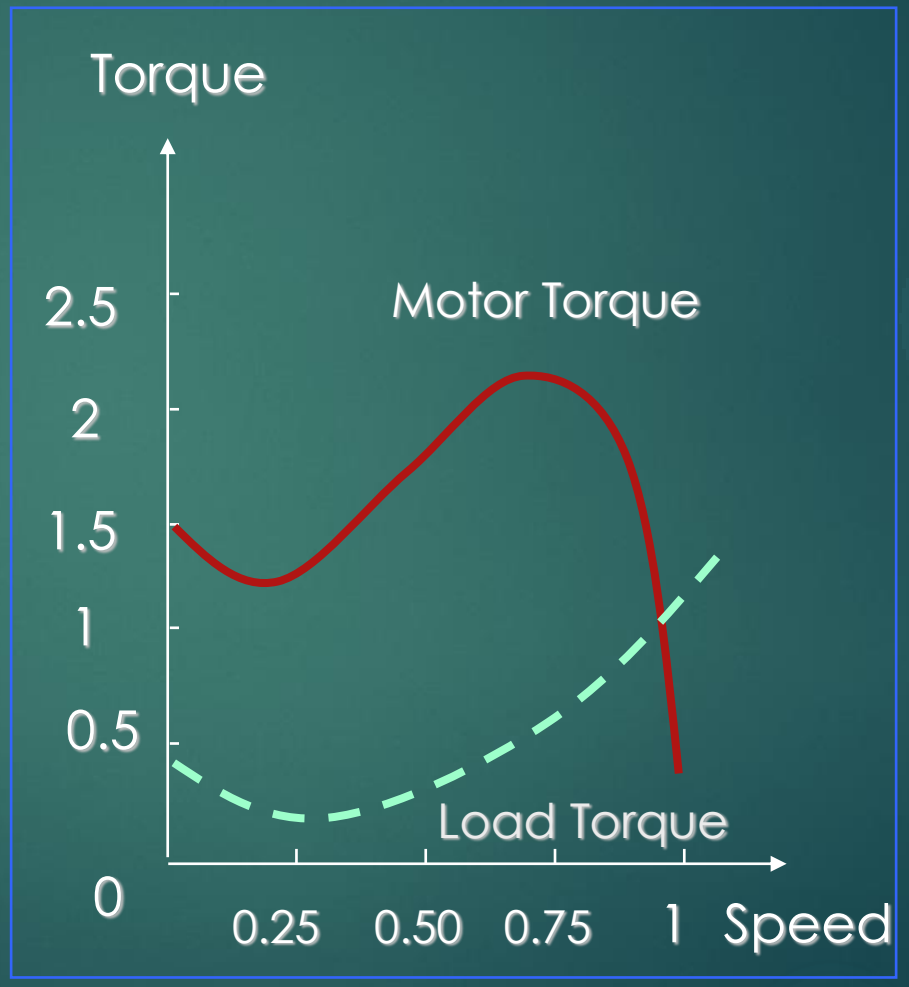


Direct On Line Starting

Current/Speed Curve



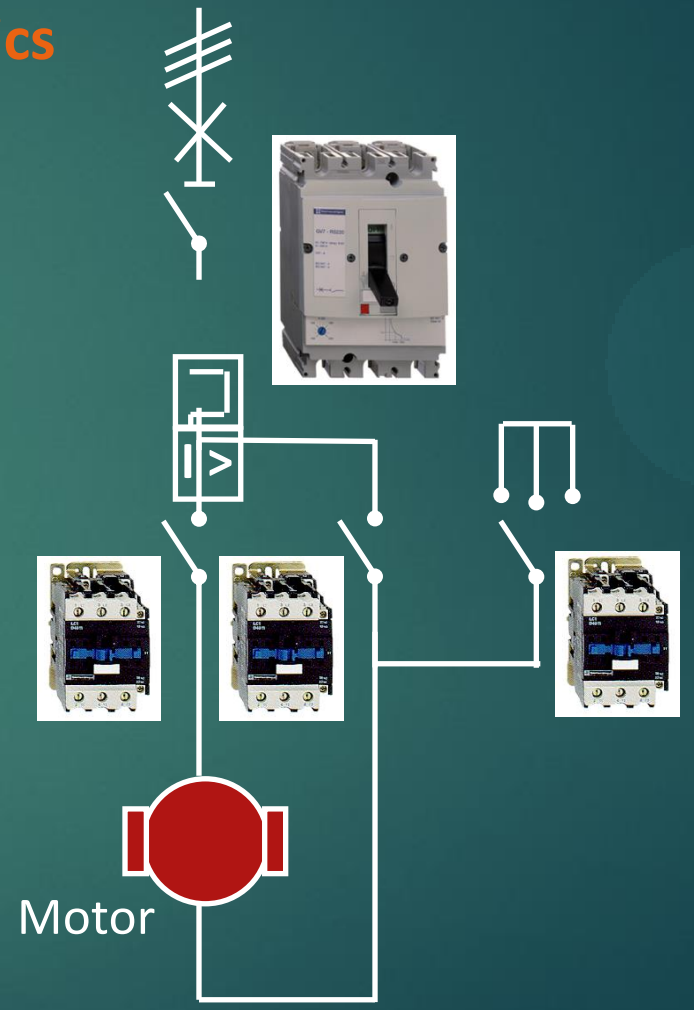
Torque/Speed Curve



Star Delta Starter

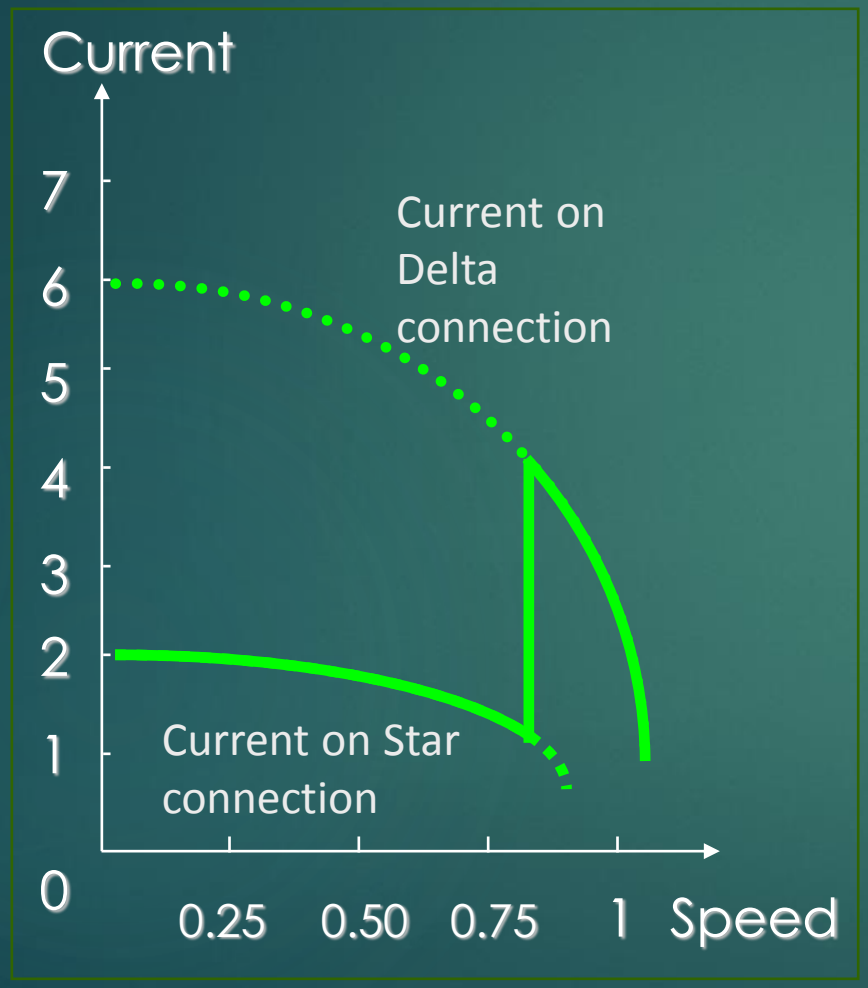
General Characteristics

- ***Starting current***
  - *1.8 to 2.6 times rated current*
- ***Starting torque****:*
  - *0.5 times rated torque*
- ***Utilisation criteria****:*
  - *6 terminal motor*
  - *starting on no-load or*
  - *with slightly resistive torque*
  - *torque peak on change from star to delta*
- ***No parameter adjustment***

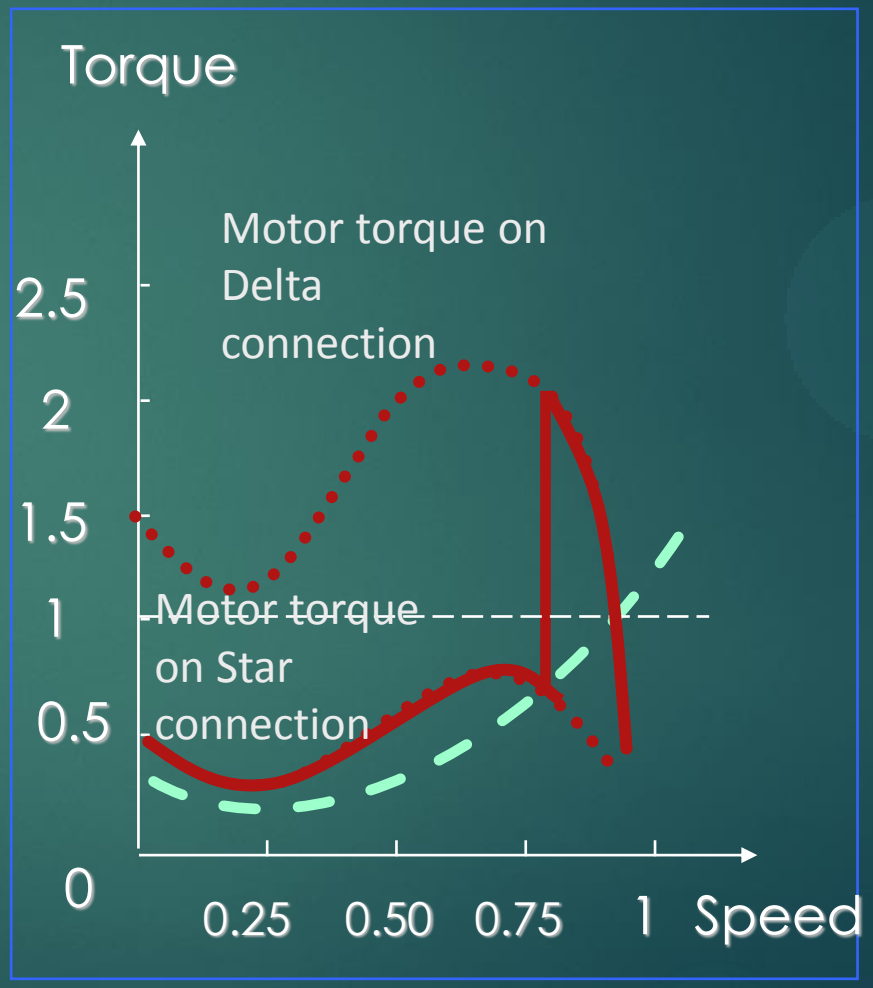


Star Delta Starting

Current/Speed Curve



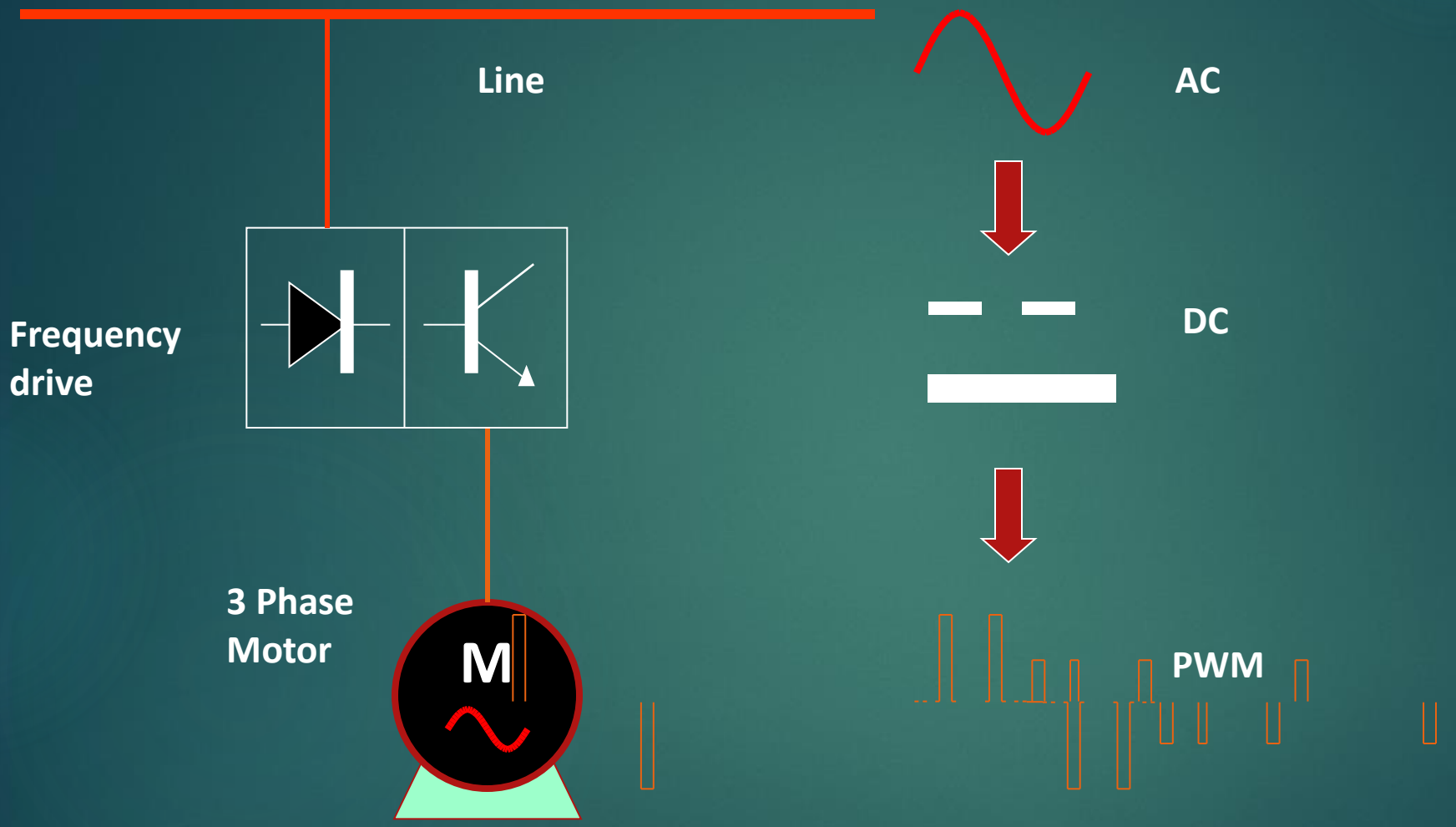
Torque/Speed Curve



Soft-starters

- Accelerations without torque peaks on the motor and the mechanical parts
- Reduce line voltage drops
- Minimize sudden current peaks during starting
- Limit the torque in order to protect persons and material being transported.
- Reduction of the installed power, economies on installed power and charges

Basic Theory



PWM - Pulse Width Modulated wave

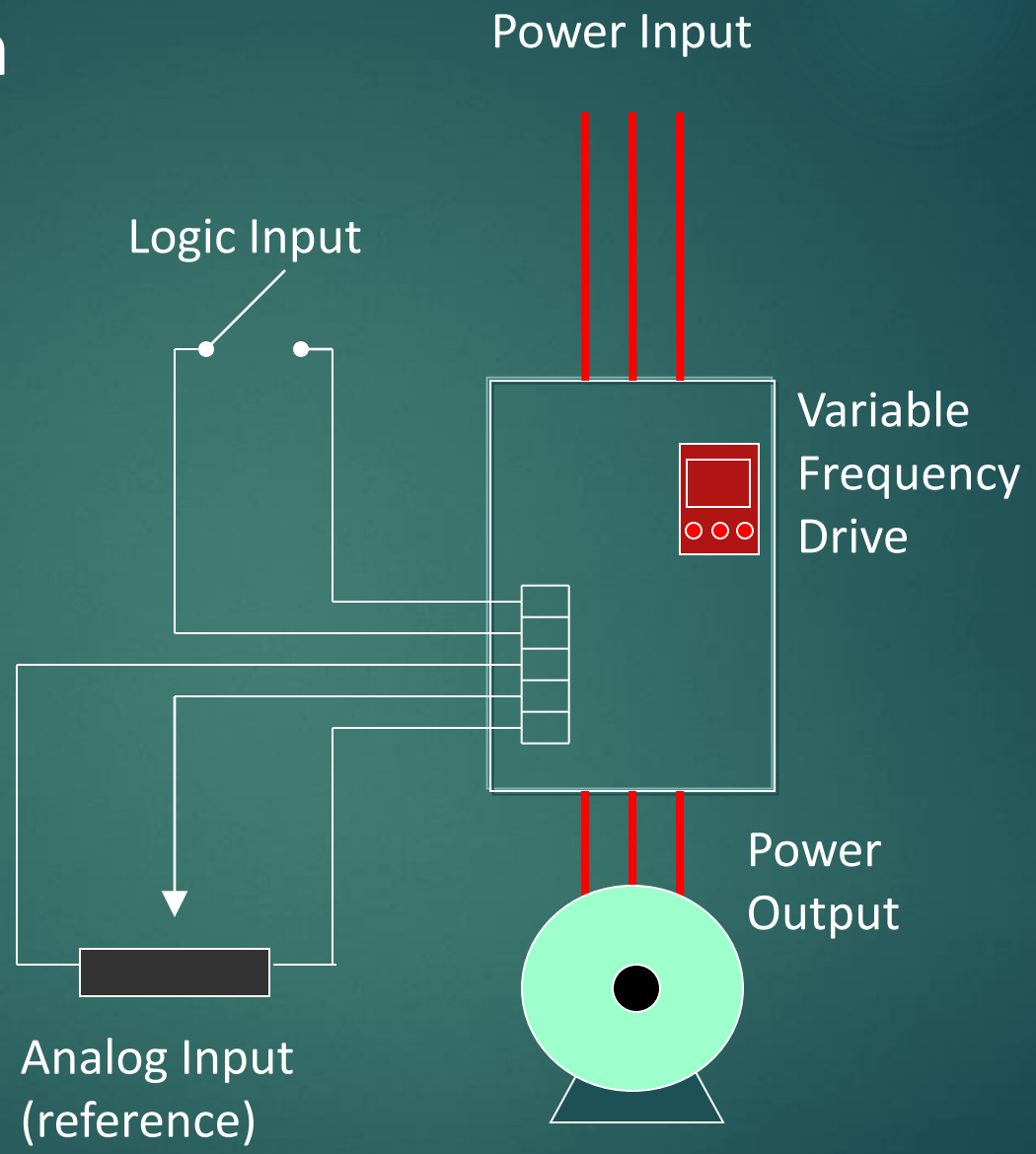
Basic Approach

Power Input: Single/ Three Phase line

Power Output: (0-Rated Volt & Frequency

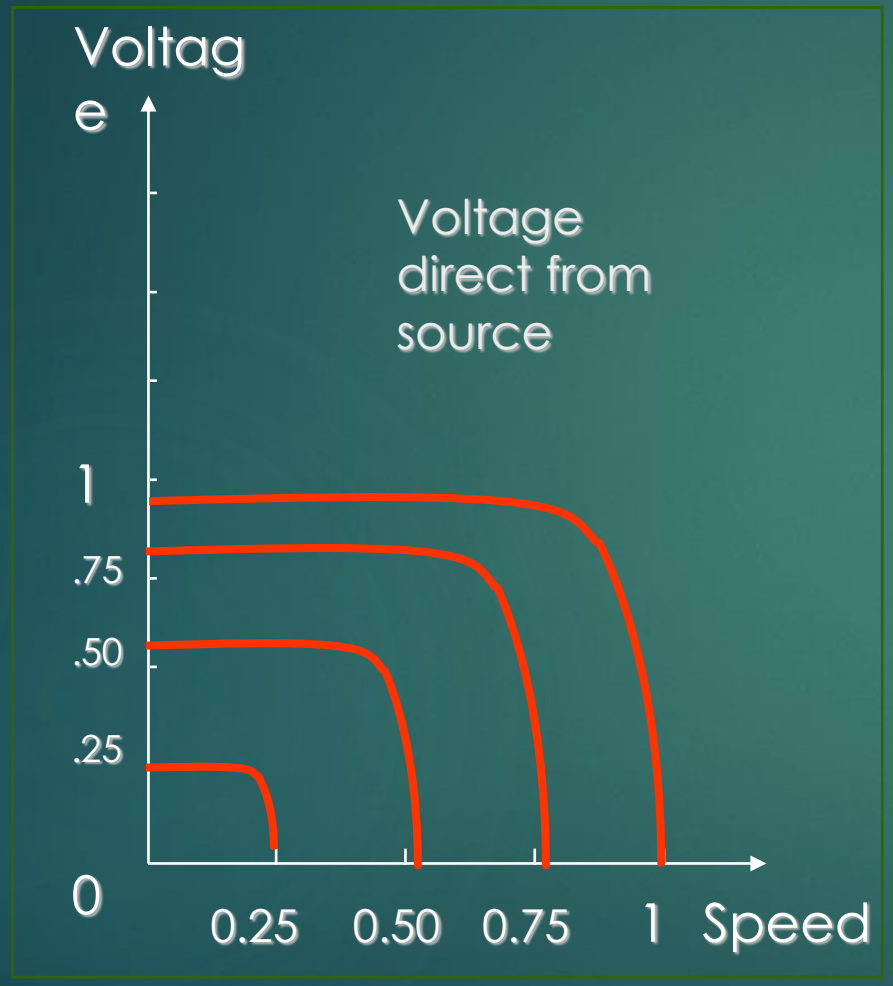
Logic Input: On/Off,
0 or 5VDC,
0 or 24VDC

Analog Input: Voltage 0-10VDC, -10-+10VDC,
Current 0-20mA, 4-20mA,a

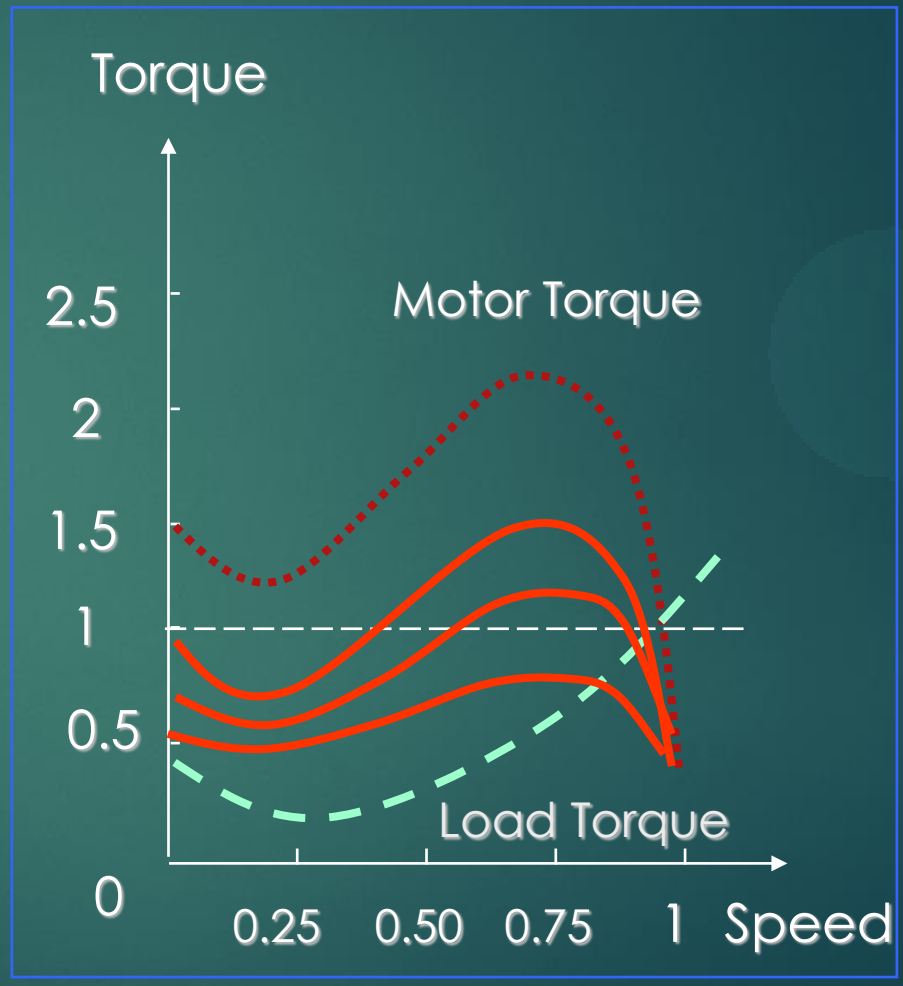


Voltage Ramping Soft Start

Voltage/Speed Curve

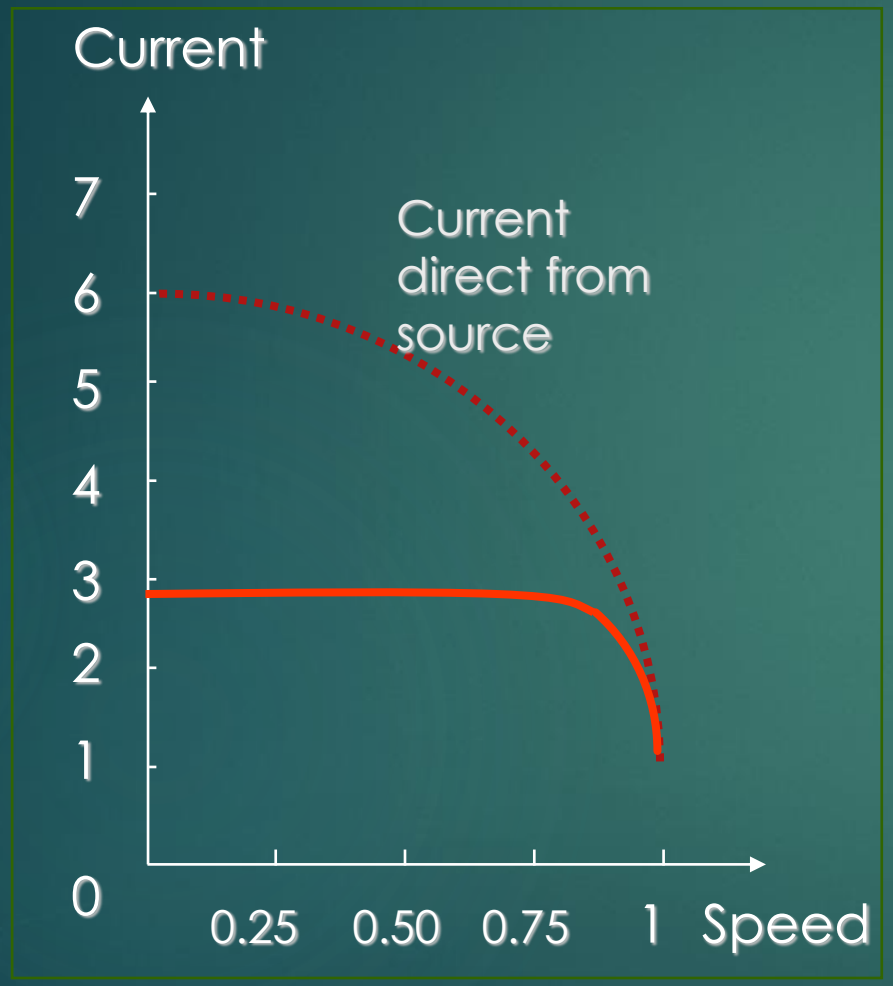


Torque/Speed Curve

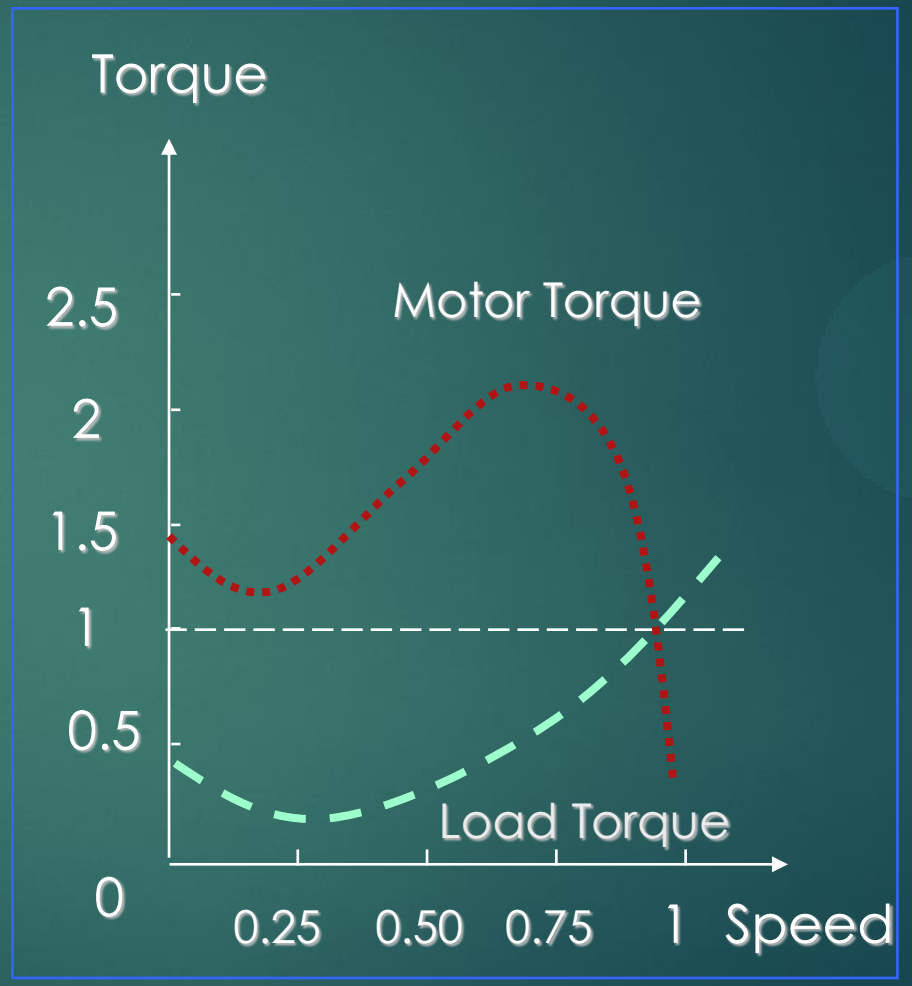


Current Limiting Soft Start

Current/Speed Curve

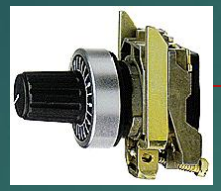


Torque/Speed Curve



PI Regulation

Reference
Set point



Constant Pressure

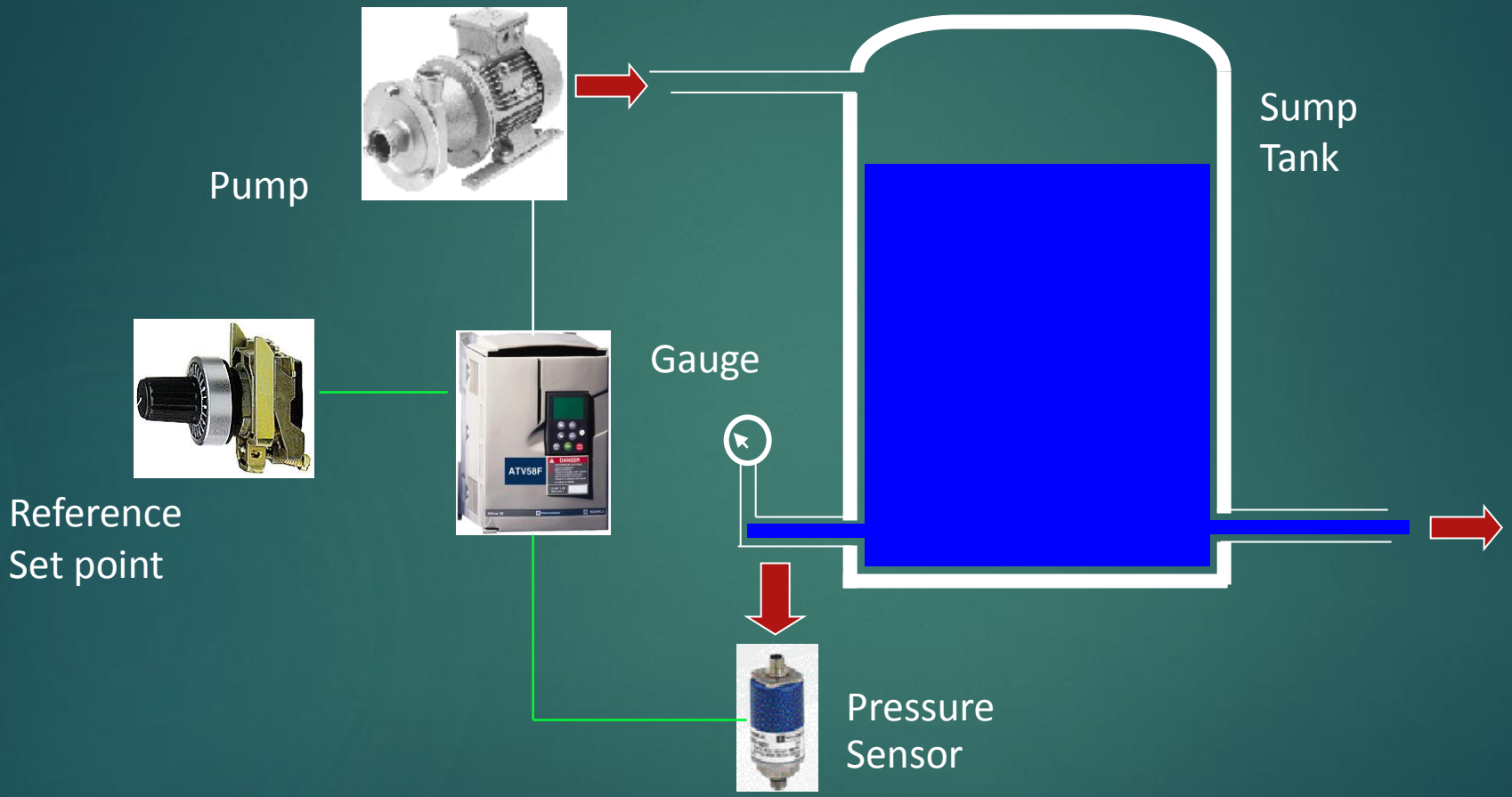
Gauge

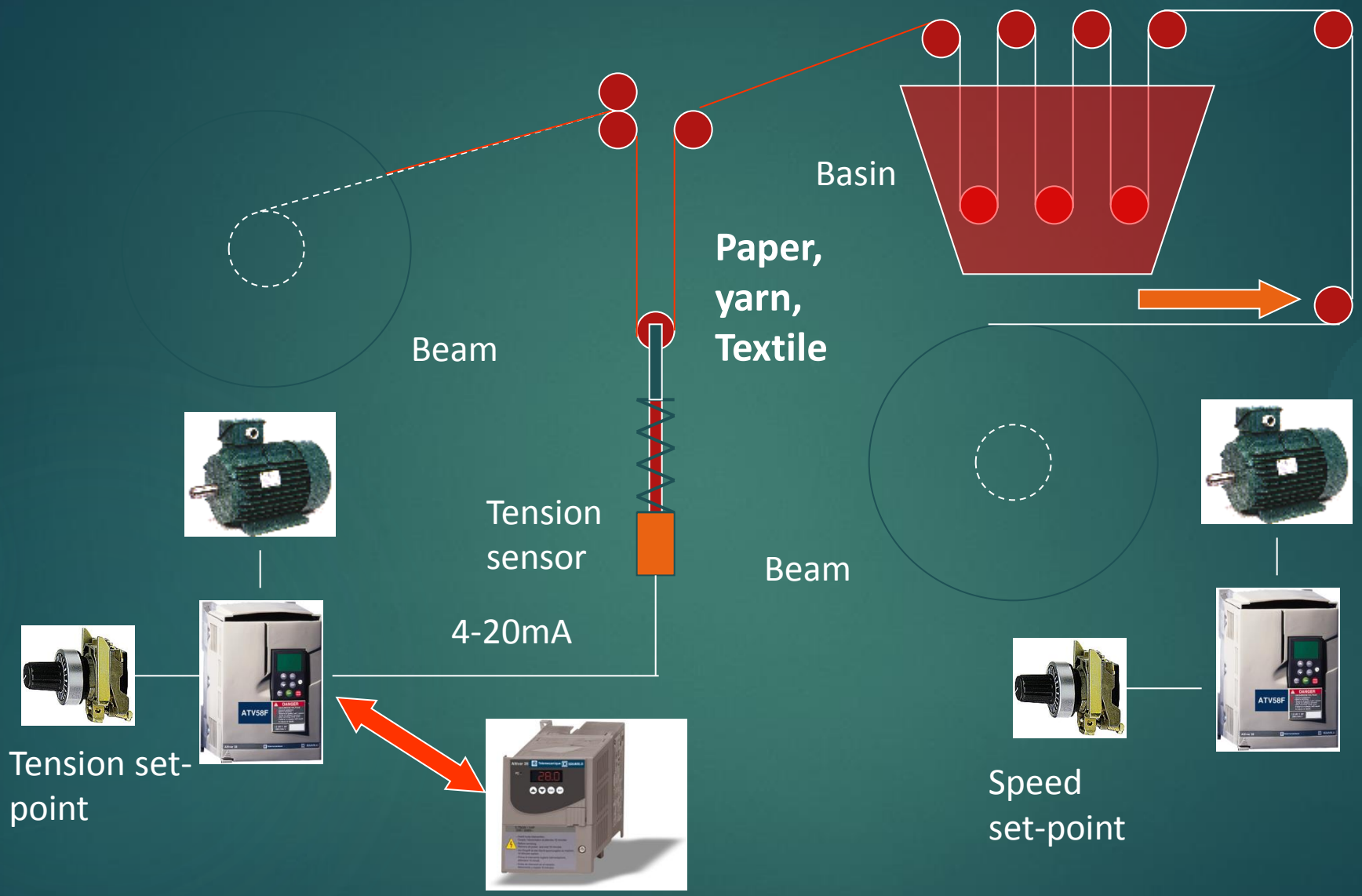
Pressure
Sensor

Pump

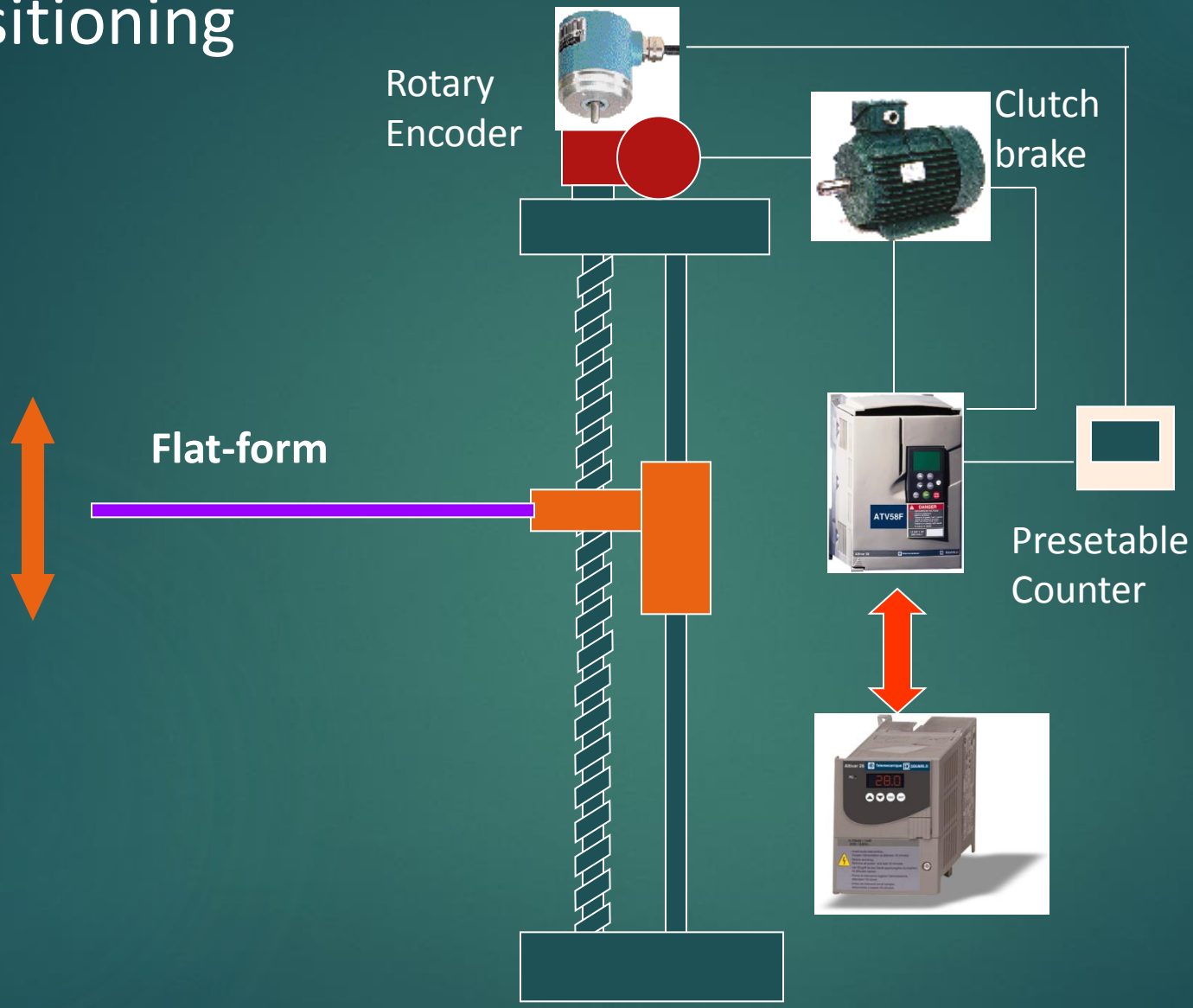
Pipe Line

Constant liquid level



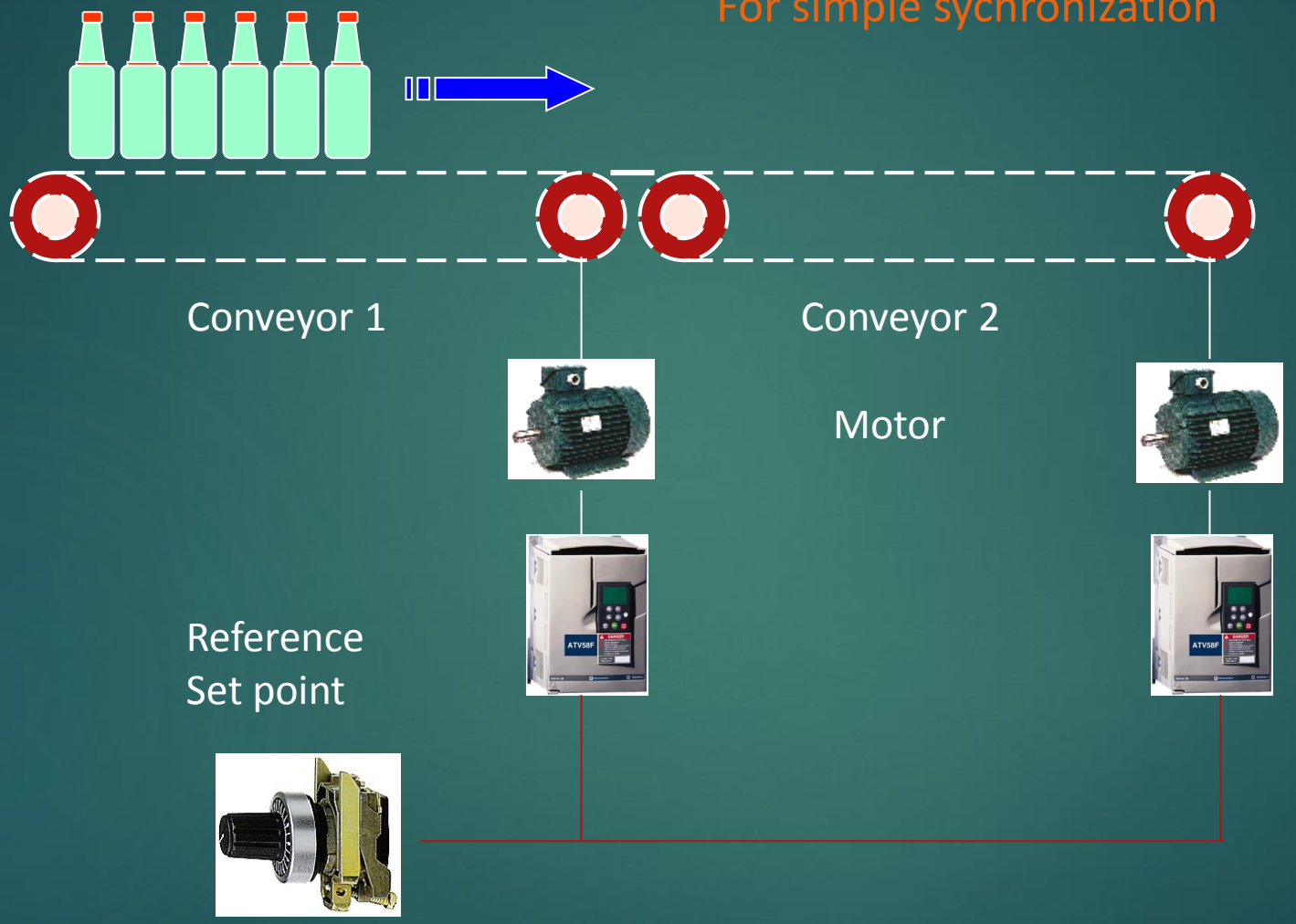

Basin
Paper,
yarn,
Textile
Beam
Tension
sensor
4-20mA
Beam
Tension set-
point
Speed
set-point

Simple positioning screw lift

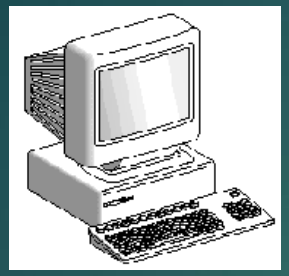


Smooth Start & Stop

For simple sychronization



Fast communication cards



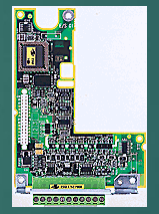
- Device-Net
- Ethernet

PLC

PLC

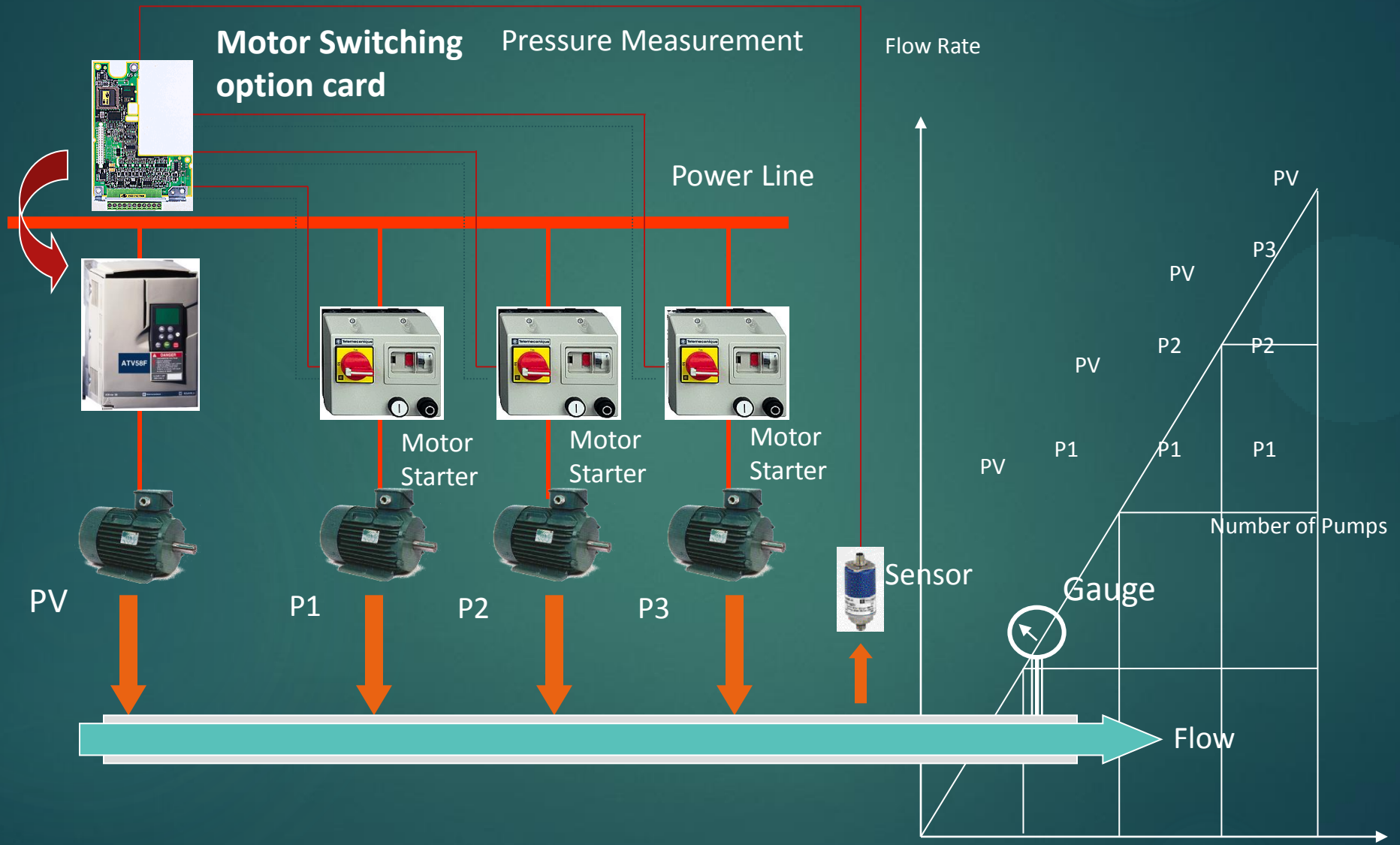
PLC

AC drive



Communication option card

Pump Switching Option



Motor Feeders

"Conductors supplying several motors, or a motor(s) and other load(s), shall have an ampacity not less than 125 percent of the full-load current rating of the highest rated motor + the sum of the full-load current ratings of all the other motors in the group + ampacity required for the other loads"

(Art. 4.30.2.4 PEC 2009, pg. 687)

Example:

Motor No.	Motor Type	HP	Voltage	Phase	FLA	CB Inverse Time	Wire THW	Service Factor	O.L.
M1	Squirrel Cage	10	230	3	28	70	8.0	1.15	35
M2	Squirrel Cage	20	230	3	54	135	22.0	1.15	67.5
M3	Squirrel Cage	25	230	3	68	170	22.0	1.0	78.2
M4	Squirrel Cage	40	230	3	104	260	50.0	1.0	119.6

Feeder Conductor : ***3 - 150mm² THW***

Feeder Protection: ***800AT, 3-P, MCCB***

Note: ***Contactors are rated in Voltage and Horsepower of the motors***

Branch Circuit Conductors* = *125% of FLA

Motor 1: (1.25)(28A) = ***35A (Use 3-8.0mm² THW)***

Motor 2: (1.25)(54A) = ***67.5A (Use 3-22.0mm² THW)***

Motor 3: (1.25)(68A) = ***72.5A (Use 3-22mm² THW)***

Motor 4: (1.25)(104) = ***130A (Use 3-50mm² THW)***

Feeder Conductor* = *125% (Largest Motor FLA) + remaining FLA's

$I_{c\ (feeder)}$ = 1.25(104A) + 28A + 54A + 68A = 280A

USE: 3 - 150mm² THW conductors

Table 3.10.1.16 Allowable Ampacities of Insulated Conductors Rated 0 Through 2000 Volts, 60°C Through 90°C (140°F Through 194°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)

Size mm²(mm dia.)	Temperature Rating of Conductor (See Table 3.10.1.13.)						Size mm²(mm dia.)
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	Types TW, UF	Types RHW, THHW, THW, THWN, XHHW, USE, ZW	Types TBS, SA, SIS, FEP, FEPB, MI, RHH, RHW-2, THHN, THHW, THW-2, THWN-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	
	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			
2.0(1.6)*	20	20	25	—	—	—	2.0(1.6)*
3.5(2.0)*	25	25	30	20	20	25	3.5(2.0)*
5.5(2.6)*	30	35	40	25	30	35	5.5(2.6)*
8.0(3.2)	40	50	55	30	40	45	8.0(3.2)
14	55	65	70	40	50	60	14
22	70	85	90	55	65	80	22
30	90	110	115	65	80	90	30
38	100	125	130	75	90	105	38
50	120	145	150	95	110	125	50
60	135	160	170	100	120	135	60
80	160	195	205	120	145	165	80
100	185	220	225	140	170	190	100
125	210	255	265	165	200	225	125
150	240	280	295	185	225	250	150
175	260	305	345	205	245	275	175
200	280	330	355	220	265	300	200
250	315	375	400	255	305	345	250

Motor Feeder Short-Circuit and Ground-Fault Protection

"The rating or setting not greater than the largest rating or setting of the branch-circuit short-circuit and ground-fault protective device for any motor supplied by the feeder [based on the table 4.30.4.2] for hermetic refrigerant motor-compressors + sum of the full-load currents of the motors of the group"

(Art. 4.30.5.2 PEC 2009, pg. 705)

Table 4.30.4.2

Table 4.30.4.2 Maximum Rating or Setting of Motor Branch-Circuit Short-Circuit and Ground-Fault Protective Devices

Type of Motor	Percentage of Full-Load Current			
	Nontime Delay Fuse[1]	Dual Element (Time-Delay) Fuse[1]	Instantaneous Trip Breaker	Inverse Time Breaker[2]
Single-phase motors	300	175	800	250
AC polyphase motors other than wound-rotor				
Squirrel cage — other than Design B energy-efficient	300	175	800	250
Design B energy-efficient	300	175	1 100	250
Synchronous[3]	300	175	800	250
Wound rotor	150	150	800	150
Direct current (constant voltage)	150	150	250	150

***Branch Circuit Protection* = 250% of FLA**

Motor 1: (2.5)(28A) = ***70A (Use 70AT, 3-P, MCCB)***

Motor 2: (2.5)(54A) = ***135A (Use 150AT, 3-P, MCCB)***

Motor 3: (2.5)(68A) = ***170A (Use 175AT, 3-P, MCCB)***

Motor 4: (2.5)(104) = ***260A (Use 300AT, 3-P, MCCB)***

***Feeder Conductor* = (Highest Protctive Device) + remaining FLA's**

$I_{c\ (feeder)}$ = (300A) + 70A + 135A + 170A = 675A

Use: 800AT, 3-P, MCCB

Motor Branch-circuit Short-circuit and Ground-Fault Protection

Table 4.30.4.2 Maximum Rating or Setting of Motor Branch-Circuit Short-Circuit and Ground-Fault Protective Devices

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Single-phase motors	300	175	800	250
AC polyphase motors other than wound-rotor				
Squirrel cage — other than Design B energy-efficient	300	175	800	250
Design B energy-efficient	300	175	1 100	250
Synchronous[3]	300	175	800	250
Wound rotor	150	150	800	150
Direct current (constant voltage)	150	150	250	150

Motor Disconnecting Means (Art. 4.30.5)

a. General

a.1 Motor Circuit Switch – a listed motor-circuit switch rated in horsepower

a.2 Molded Case Circuit Breaker – a listed molded case circuit breaker

a.3 Molded Case Switch – a listed molded case switch

Motor Disconnecting Means

b. Stationary Motors of 1/8 Horsepower or Less

The branch-circuit overcurrent device shall be permitted as the disconnecting means.

c. Stationary Motors of 2 Horsepower or Less

c.1 On general-use switch having an ampere rating not less than *twice* of the full-load current rating of the motor

c.2 On AC circuits, general-use snap switch suitable only for use on AC where the current rating is not more than *8 percent* of the ampere rating of the switch.

Motor Disconnecting Means

d. Autotransformer-type Controlled Motors

d.1 Should be provided with overload protection

d.2 The controller is interrupting the locked-rotor current of the motors [Table 4.30.1.7(b)] and provided with running overload protection not exceeding *125%* of the motor full-load current rating.

d.3 Separate fuses or inverse-time circuit breakers are set not more than *150%* of the motor full-load current.

Table 4.30.1.7(b)

Table 4.30.1.7(b) Locked-Rotor Indicating Code Letters

Code Letter	Kilovolt-Amperes per Horsepower with Locked Rotor
A	0–3.14
B	3.15–3.54
C	3.55–3.99
D	4.0–4.49
E	4.5–4.99
F	5.0–5.59
G	5.6–6.29
H	6.3–7.09
J	7.1–7.99
K	8.0–8.99
L	9.0–9.99
M	10.0–11.19
N	11.2–12.49
P	12.5–13.99
R	14.0–15.99
S	16.0–17.99
T	18.0–19.99
U	20.0–22.39
V	22.4 and up

Motor Circuit Conductor (Art. 4.30.2)

a. General

"The ampacity of the conductor not less than *125%* of the motor's full-load current rating ".

b. Multispeed Motor

"The conductors on the line side should be based on the highest of the full-load current ratings shown on the motor nameplate".

"The conductors between the controller and the motor shall be based on the current rating of the windings".

Motor Circuit Conductor (Art. 4.30.2)

c. Wye-Start, Delta-Run Motor

"The conductors on the line side should be based on the motor full-load current".

"The conductors between the controller and the motor shall be based on *58%* of the motor full-load current.

Motor Controller (Art. 4.30.7)

General Controller Design

1. *Horsepower Ratings*

   It shall have horsepower ratings at the application voltage not lower than the horsepower rating of the motor.

2. *Circuit Breaker*

   The inverse time circuit breaker rating shall be permitted as a controller for all motors.

Motor Controller (Art. 4.30.7)

Torque Motors Controller Design

"the controller shall have a continuous-duty, full-load current rating not less than the nameplate current of the motor".

Voltage Rating

- A controller with a straight voltage rating (240V or 480V) shall be permitted.
- A controller with a slash rating (240/120V or 480Y/277) shall only be applied in a solidly grounded circuit.

Motor Overload Protection (Art. 4.30.3)

(1) Separate Overload Device

This device shall be selected to trip or no more than the following percent of the motor nameplate full-load current rating:

Motors with a marked service factor 1.15 or greater	125%
Motors with a marked temp. rise 40˚C or less	125%
All other motors	115%

Secondary Resistor (Art. 4.30.2.3)

(2) Thermal Protector

This device shall protect on the basis that will prevent dangerous overheating of the motor due to overload and starting failure.

Motor full-load current 9 Amps. or less	170%
Motors full-load current from 9.1 to, and including 20 Amps.	156%
Motor full-load current greater than 20 Amps.	115%

Motor Overload Protection (Art. 4.30.3)

(3) Selection of Overload Relay

Motors with marked service factor 1.15 or greater	140%
Motors with a marked temperature rise 40˚C or less	140%
All other motors	130%

THANK YOU AND GOD BLESS