Considerations

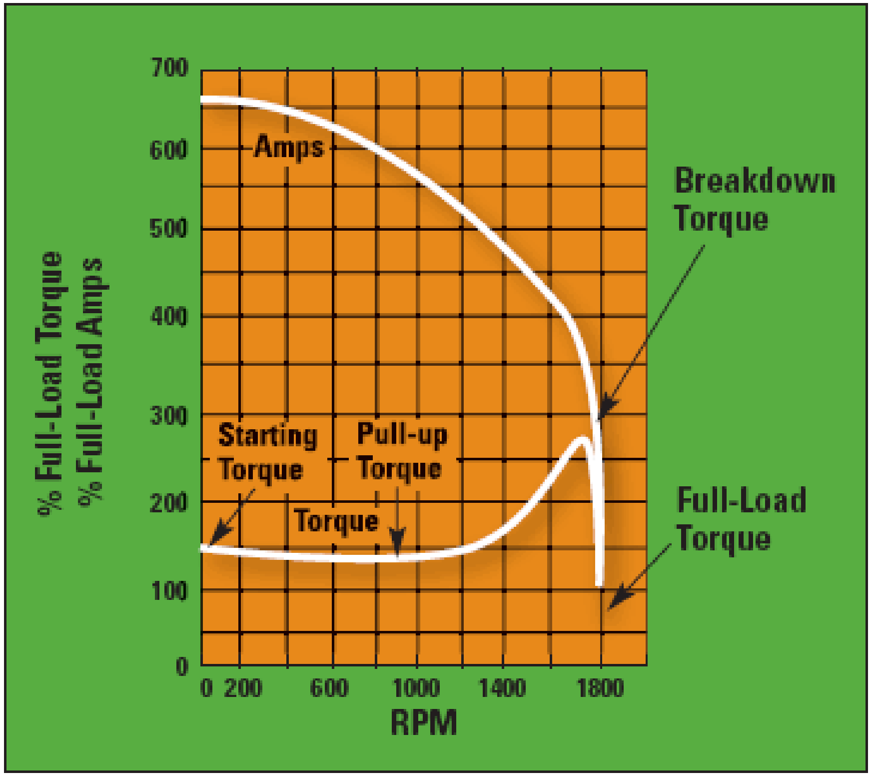
for

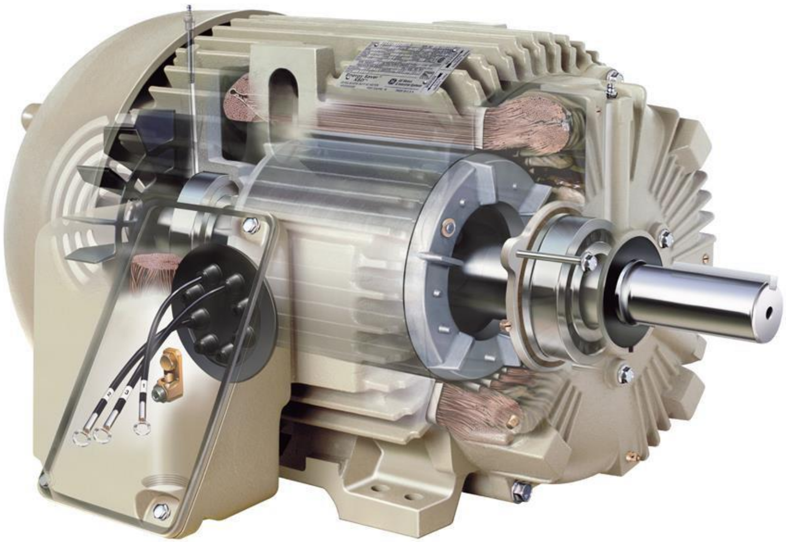
Energy & Process Upgrades

Control Considerations

Squirrel Cage
AC Motors

NEMA Design B Motor Curves

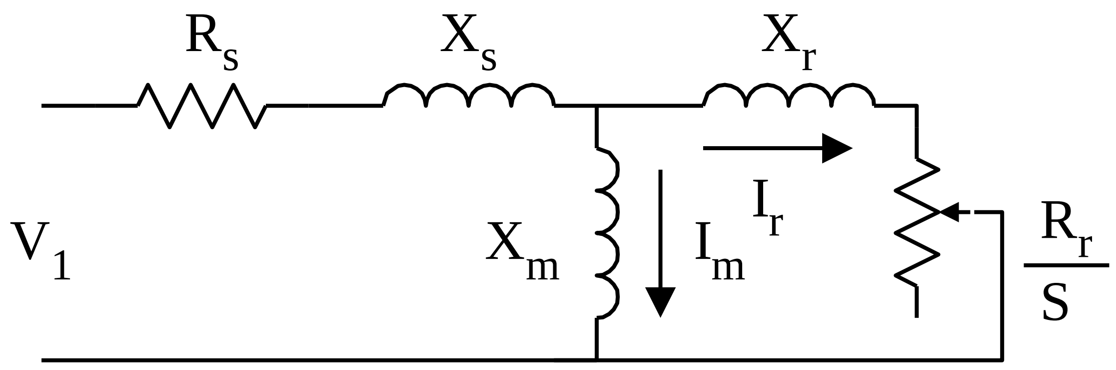




Putting Amps to Work!

Where Does Torque Come From ?

- Torque is the product of magnetizing flux and rotor current
- Magnetizing flux is proportional to the transverse (mutual) current, I_m
- Rotor current is the current flowing through the rotor bars, I_r



Torque (T) ~ Air Gap Flux (F) ~ $(V/Hz)^2$

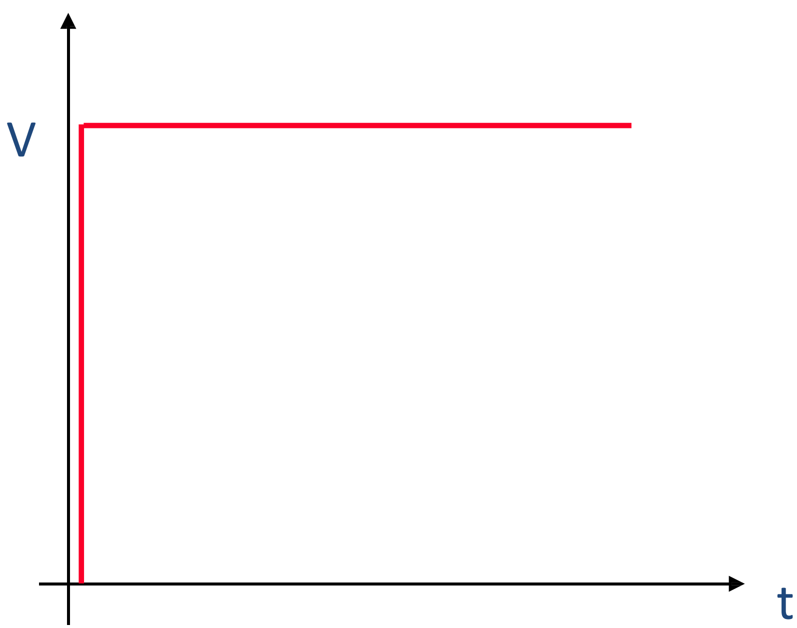
Motor Control Methods

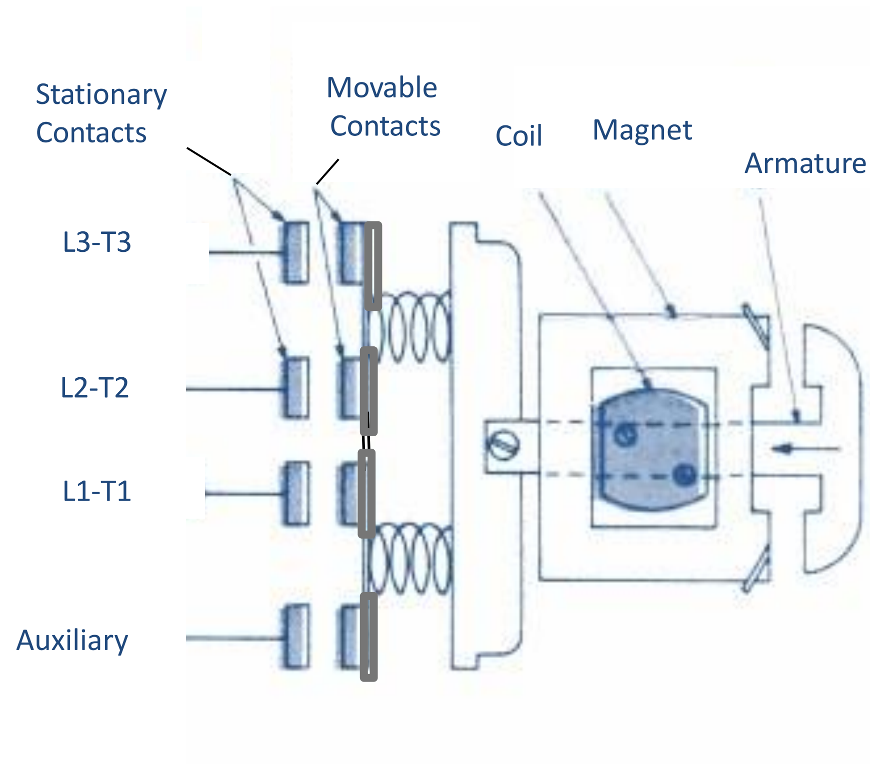
There are four basic methods for starting & controlling squirrel cage motors:

- **Full Voltage** – Across the Line or Direct On Line
- **Reduced Voltage** - Electro mechanical methods
- **Reduced Voltage** - Electronic methods
- **Reduced Voltage/Frequency** - Electronic methods

Full Voltage

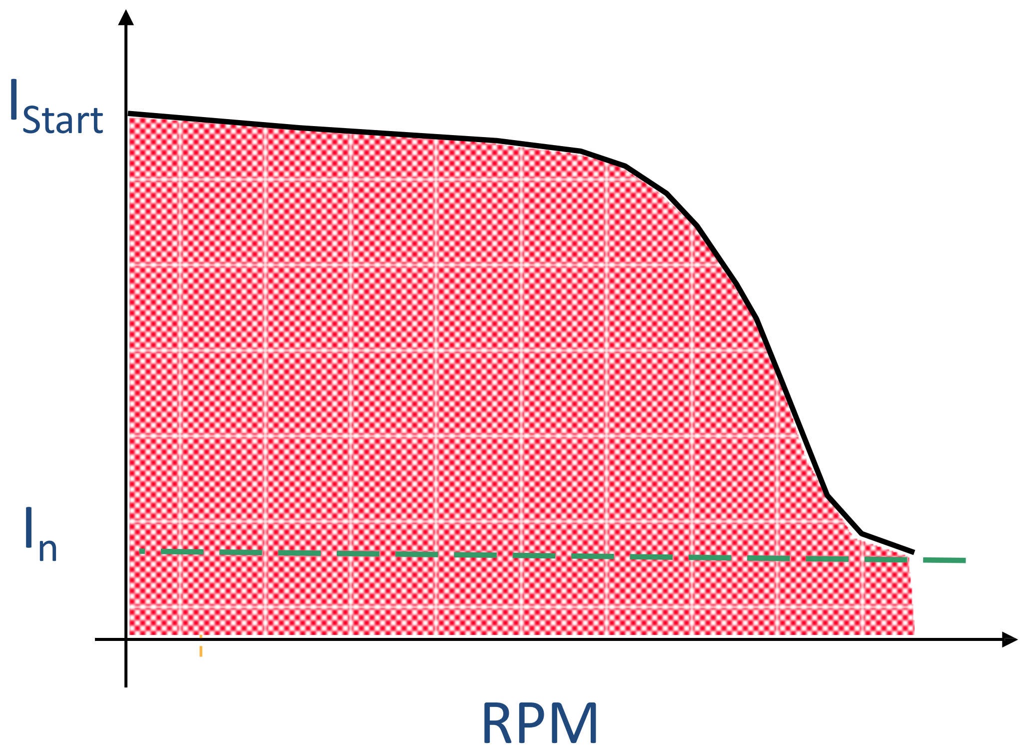
Starting Voltage - Across the Line or Direct On Line starting at 100% Voltage with NEMA or IEC Electro-Mechanical Contactor

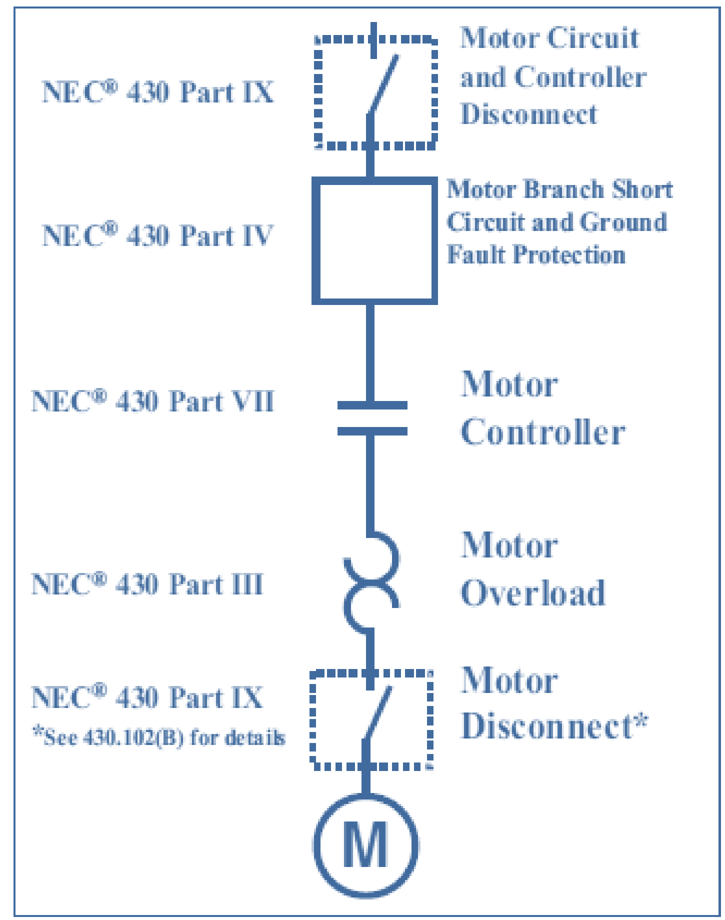




Full Voltage

Starting Current - Typically 500-850% nominal current, depends on motor design

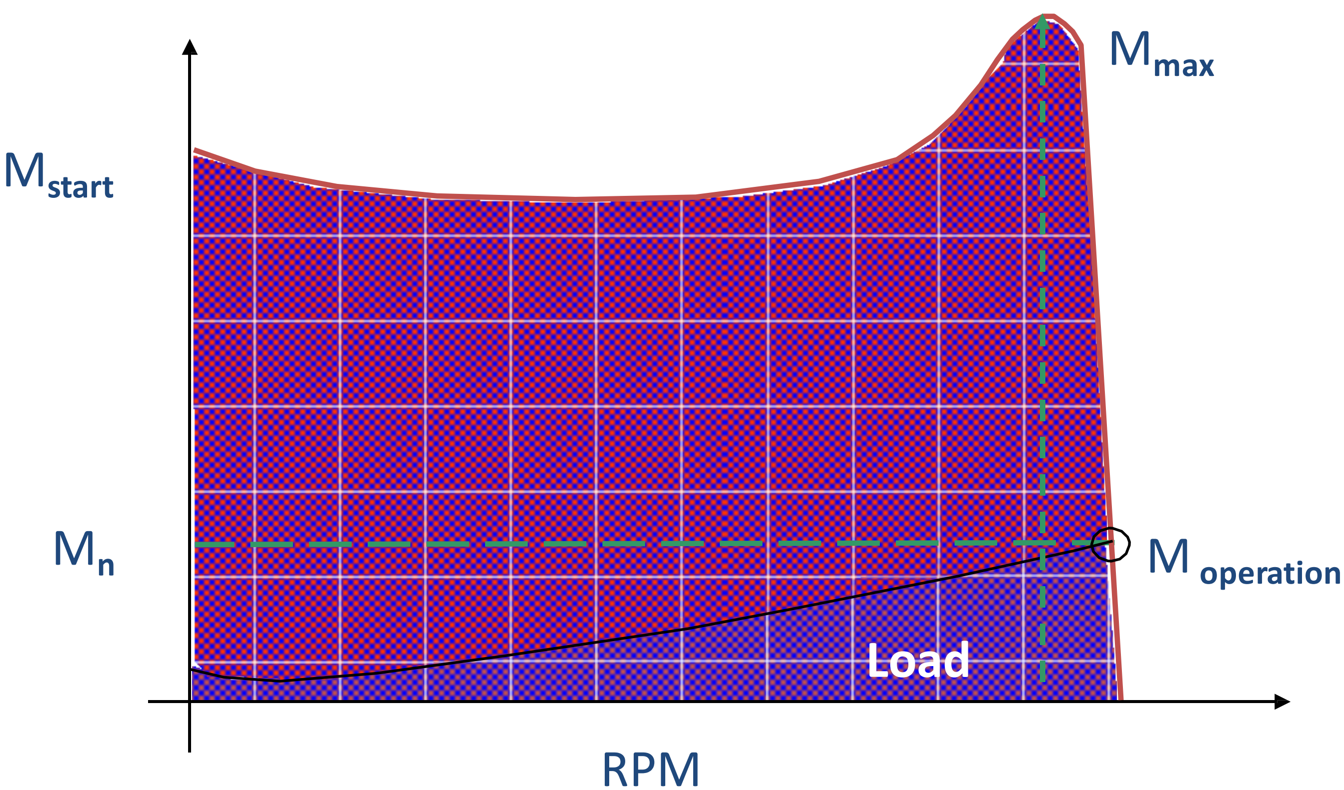




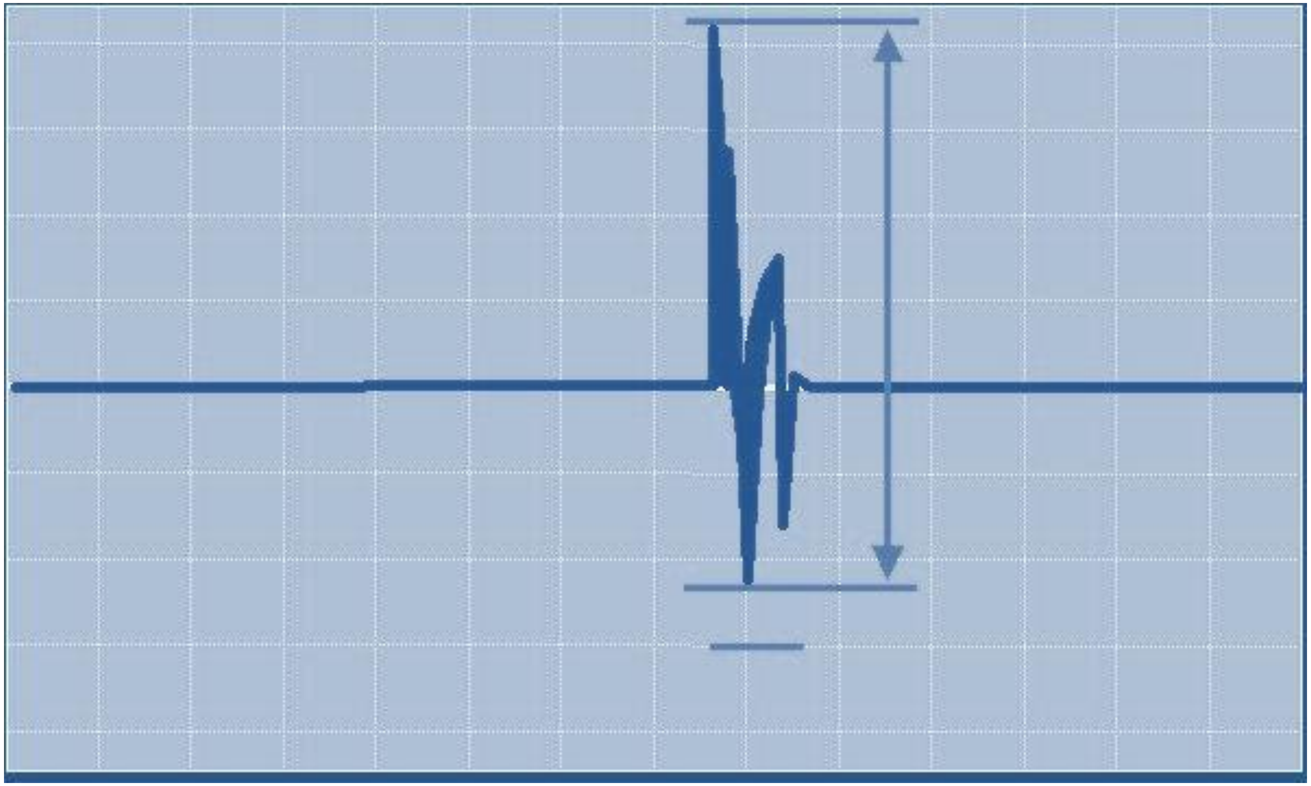
Full Voltage

Starting Torque (M_{start}) - Typically 150 - 180%

Max Torque (M_{max}) - Break Down Torque can reach 220%



Full Voltage



Mechanical Shock

Full Voltage

Advantages:

- ✓ Simple
- ✓ Small size
- ✓ Low price

Disadvantages:

- ✓ High inrush current 500-850% In which may cause voltage drops in supply system, nuisance tripping & light dimming
- ✓ High starting torque 150-250% Min. which may cause mechanical damages to gears, transmissions and fragile loads

Reducing Starting Current & Torque

Reducing Inrush Current is Essential :

- When starting from weak power supplies like fully loaded transformers, long motor cables, diesel generators, etc.
- To reduce peak energy demand

Reducing mechanical shock is essential :

- To increase life expectancy of belts, gears, shafts and motors
- To reduce maintenance requirements
- To prevent damage to fragile loads

Reducing Starting Current & Torque

✓Reducing Inrush Current & Mechanical Shock in squirrel cage motors can be done by reducing motor voltage during starting

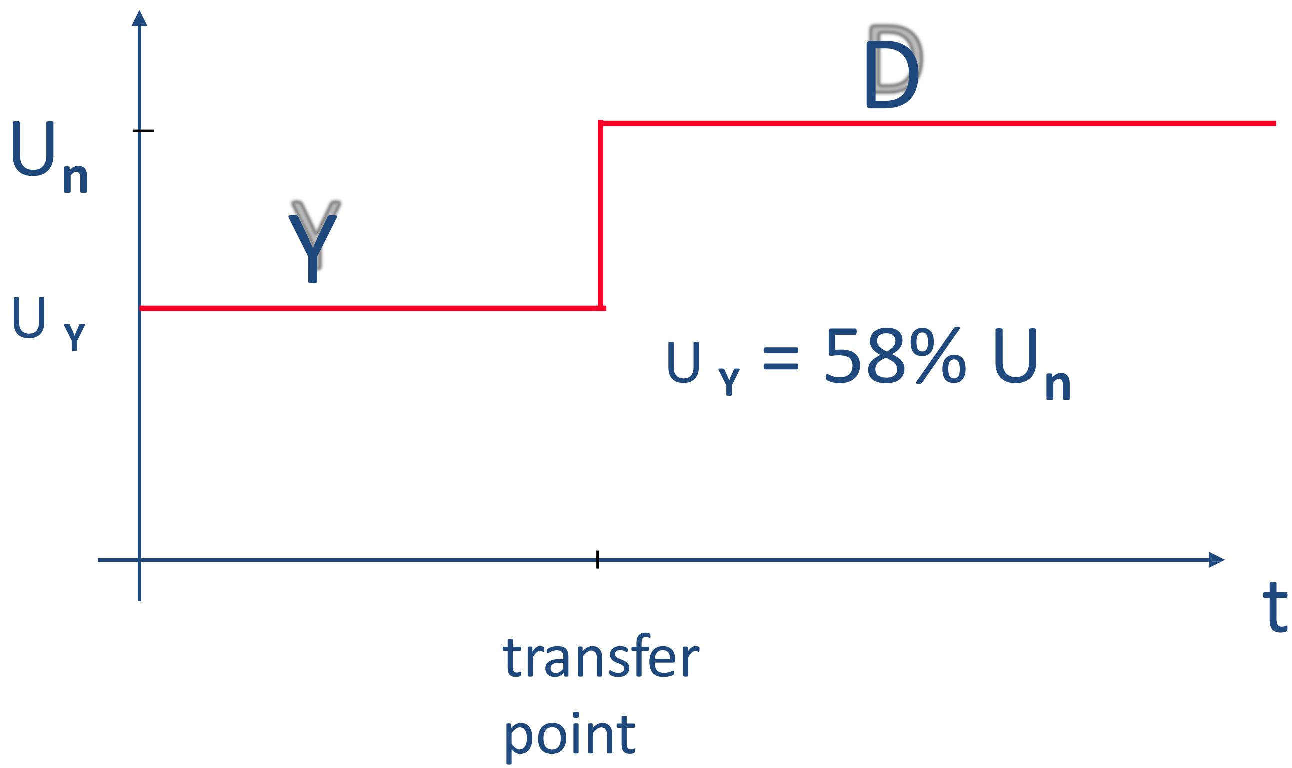
✓Reducing voltage during starting can be done by the traditional electro-mechanical systems like Star-Delta, Auto-transformer, Part winding, Starting Resistors or by Electronic Reduced Voltage Soft Starters

✓ When Starting Voltage is reduced:

- Starting torque is reduced in square proportion to voltage reduction
- Starting current is reduced in direct or square proportion to voltage reduction - depending on starting method

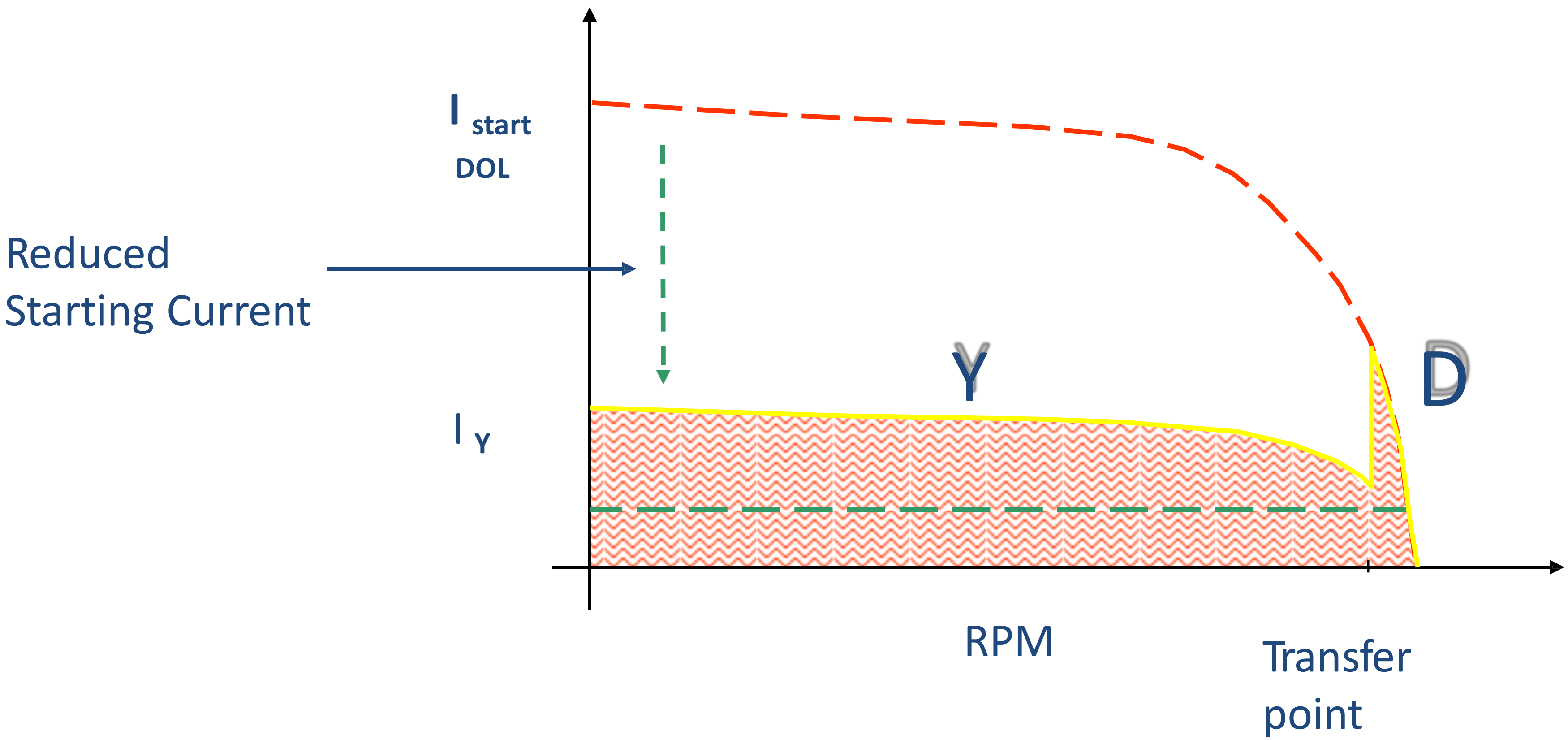
WYE/Delta Starters

Starting Voltage - Wye connected (58% Un), transfer to Delta (100% Un) by timer - Open Loop Control



WYE/Delta Starters

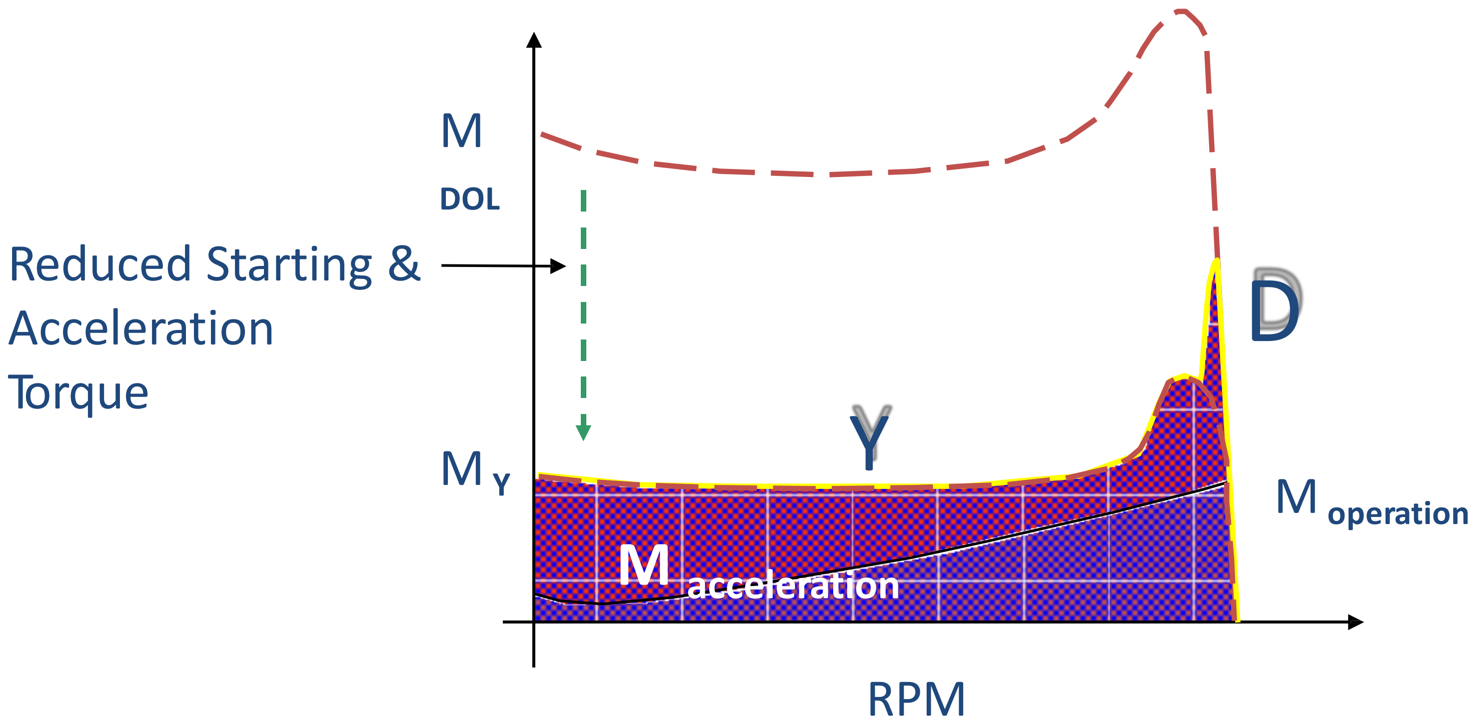
Starting Current - Typically 250% In, current is reduced in square proportion to voltage reduction



WYE/Delta Starters

Starting Torque - Reduced by the square proportion to voltage reduction, the voltage remains constant during most of the starting time

$$M_{start\ Y} = (0.58)^2 \times M_{start\ (DOL)} = 0.33 \times M_{start\ (DOL)}$$



WYE/Delta Starters

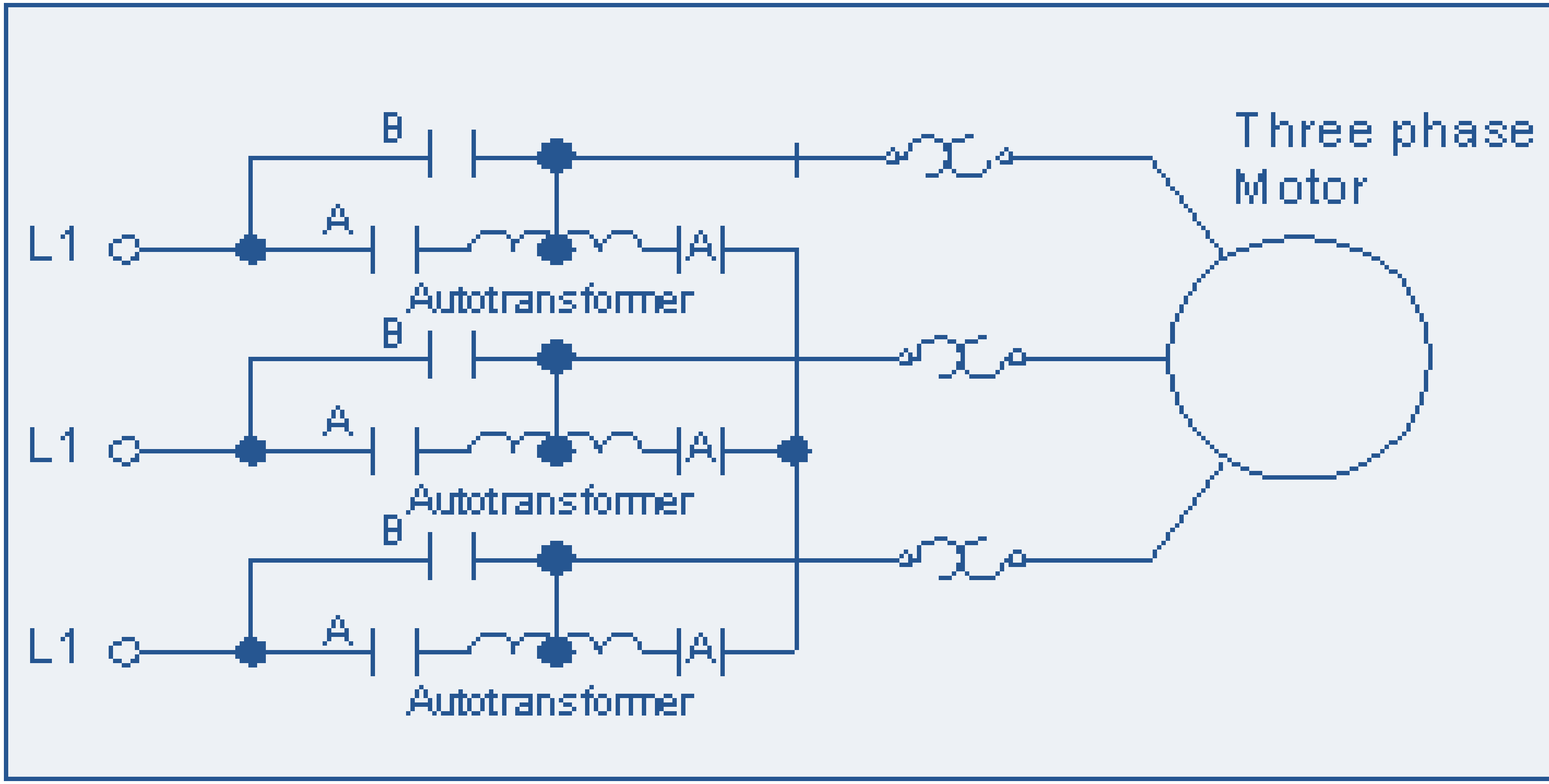
Advantages:

- ✓ Simple
- ✓ Small size
- ✓ Inexpensive (in lower ratings)
- ✓ Lower starting currents

Disadvantages:

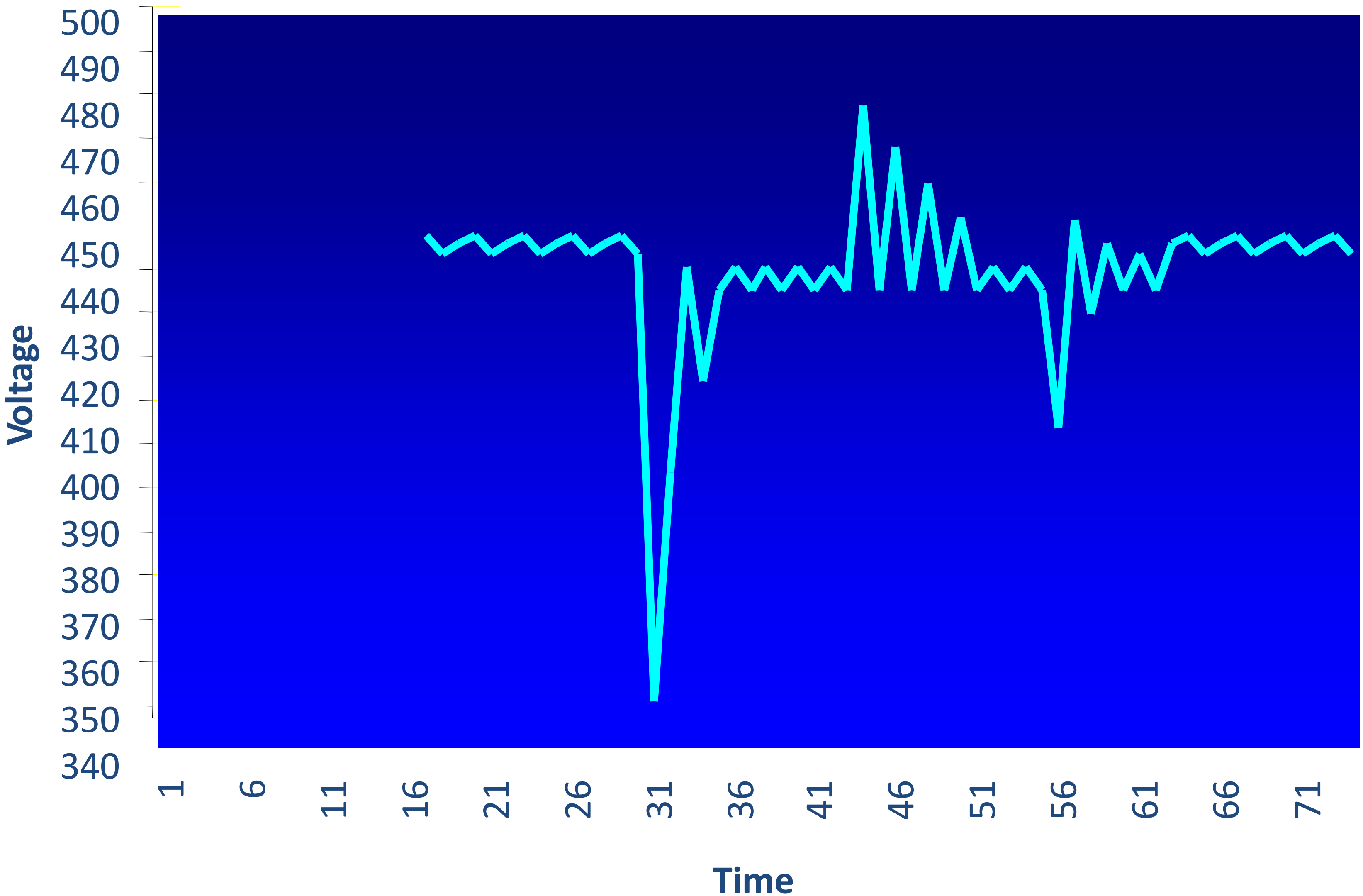
- ✓ Non-adjustable starting characteristics
- ✓ Possible high switching current & torque (expensive closed transition option)
- ✓ Open loop control
- ✓ 6 wires to the motor
- ✓ No optional features (only soft start)
- ✓ Only Thermal Overload protection

Auto-Transformer Starters



Auto-Transformer Starters

Voltage drop as viewed below by Oscilloscope



Auto-Transformer Starters

Advantages:

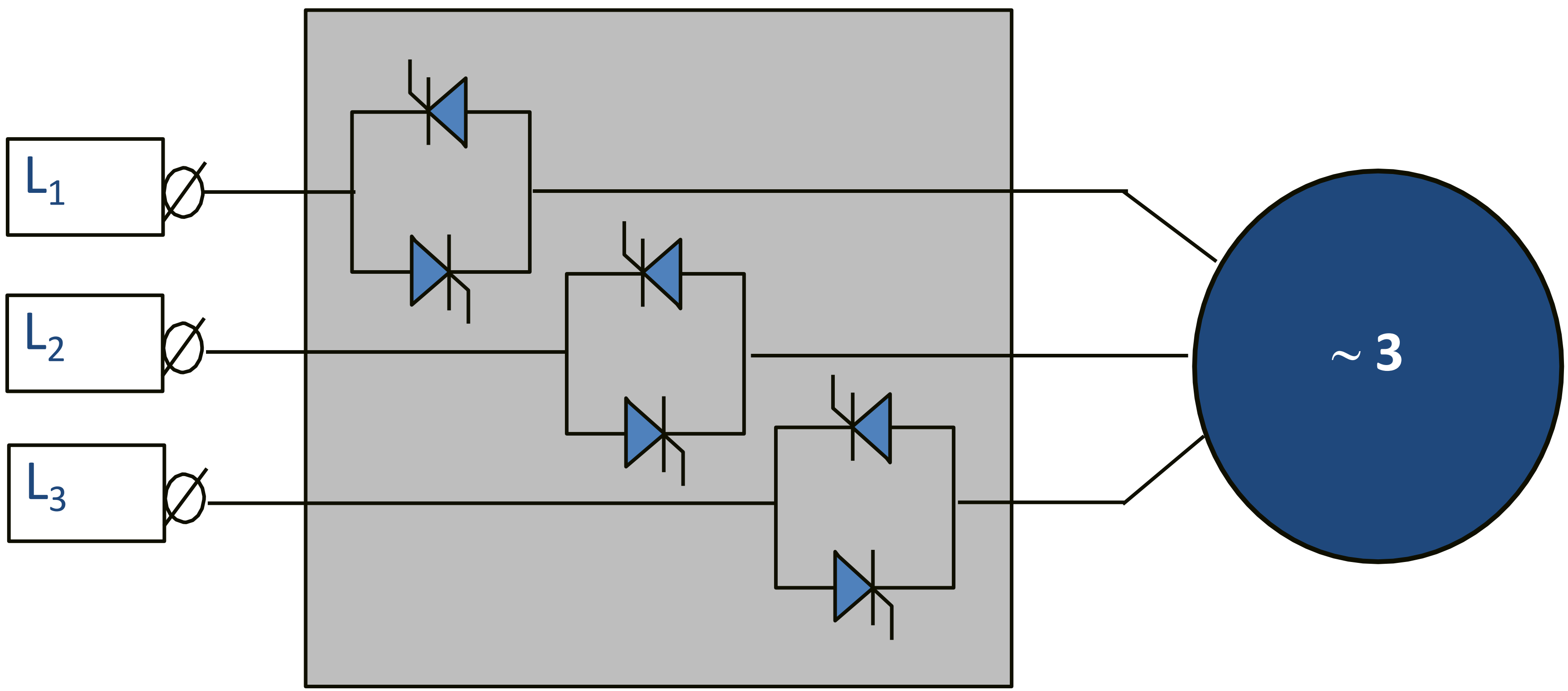
- ✓ Lower starting currents

Disadvantages:

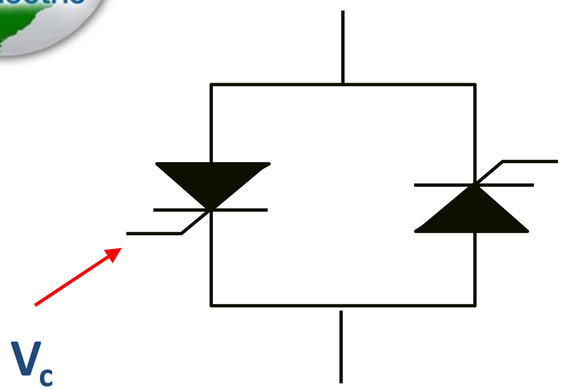
- ✓ 25% Voltage Drop during start (previous slide)
- ✓ Bulky
- ✓ Expensive
- ✓ Limited number of operations per hour
- ✓ Inability to soft-stop (major disadvantage in pumps)
- ✓ Complicated change of starting parameters
- ✓ Switching transients - expensive closed transition

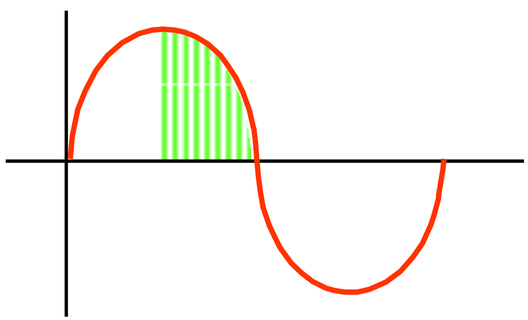
Soft Starters

Using 6 SCR's, 2 per phase, in a back to back connection



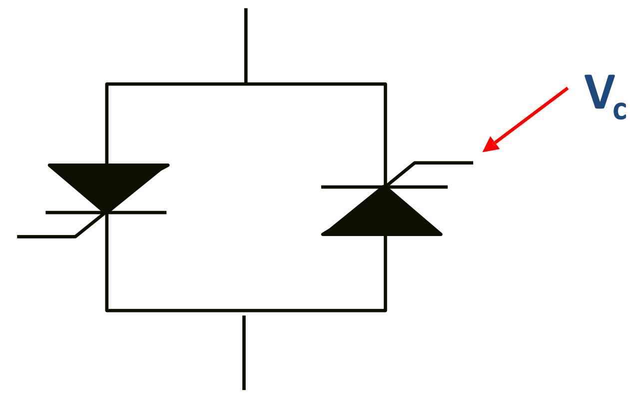
Soft Starters

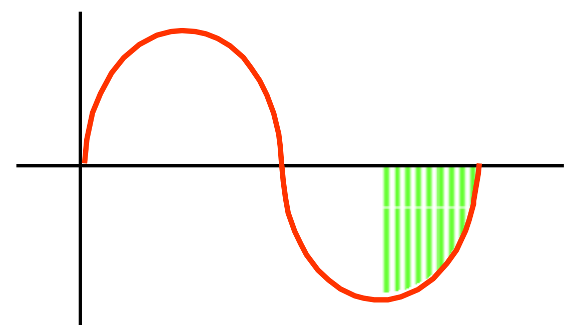




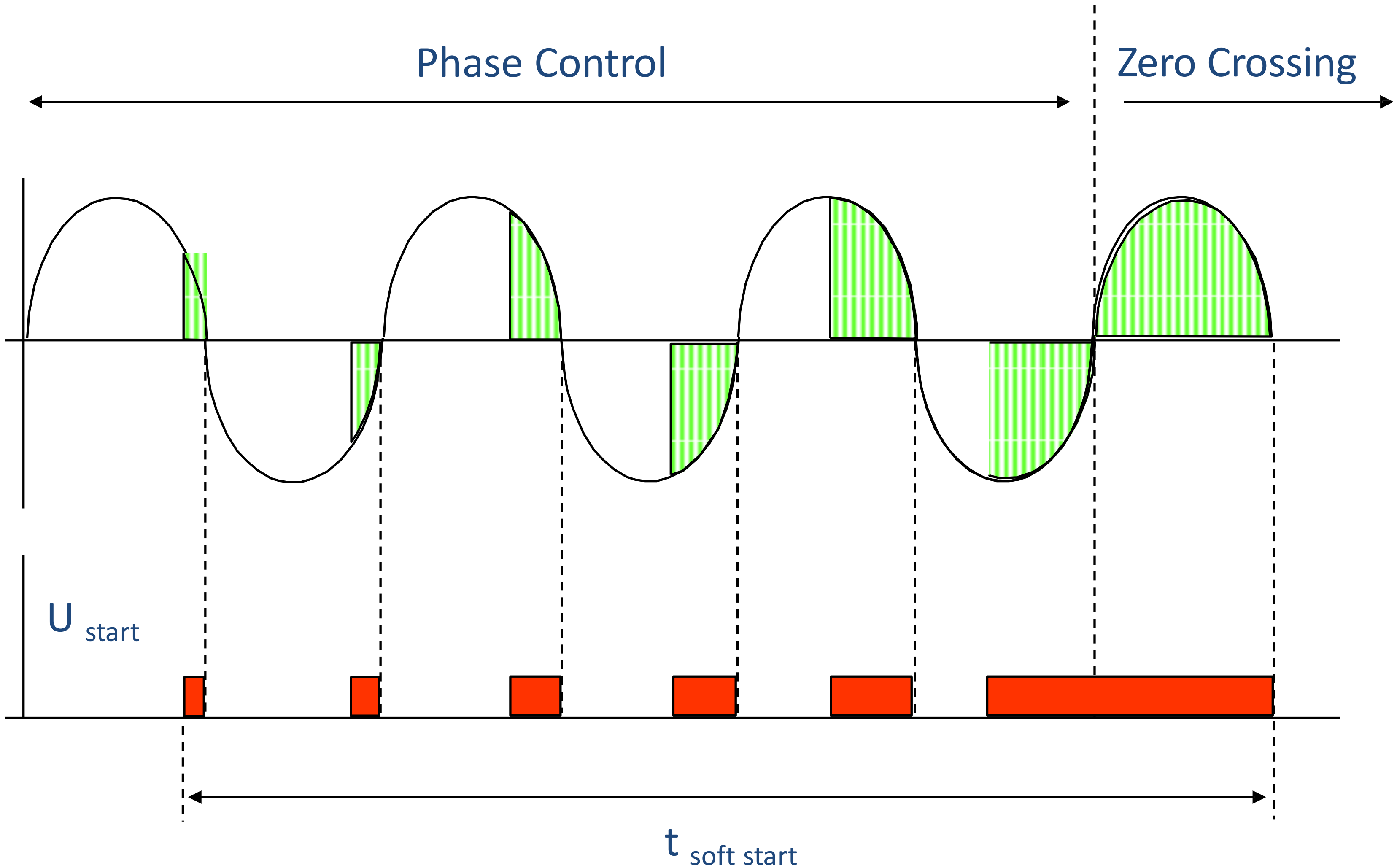
The left SCR conducts during the positive period of the sine wave, when V_c is On and can be turned Off when the current is at zero crossing

The other SCR is coupled in an anti-parallel method and conducts in the negative half cycle

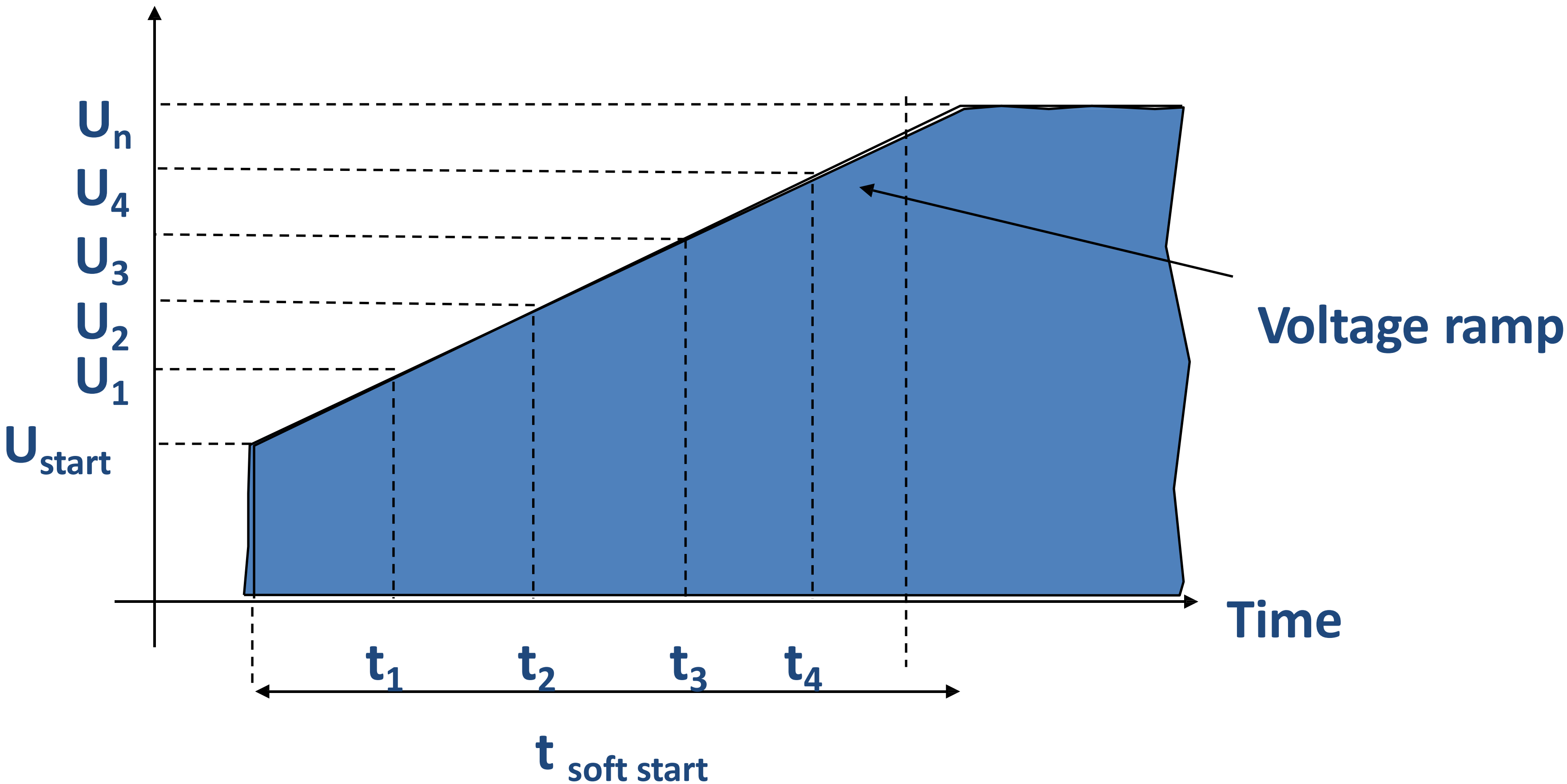




SCR firing controls the soft starter output voltage

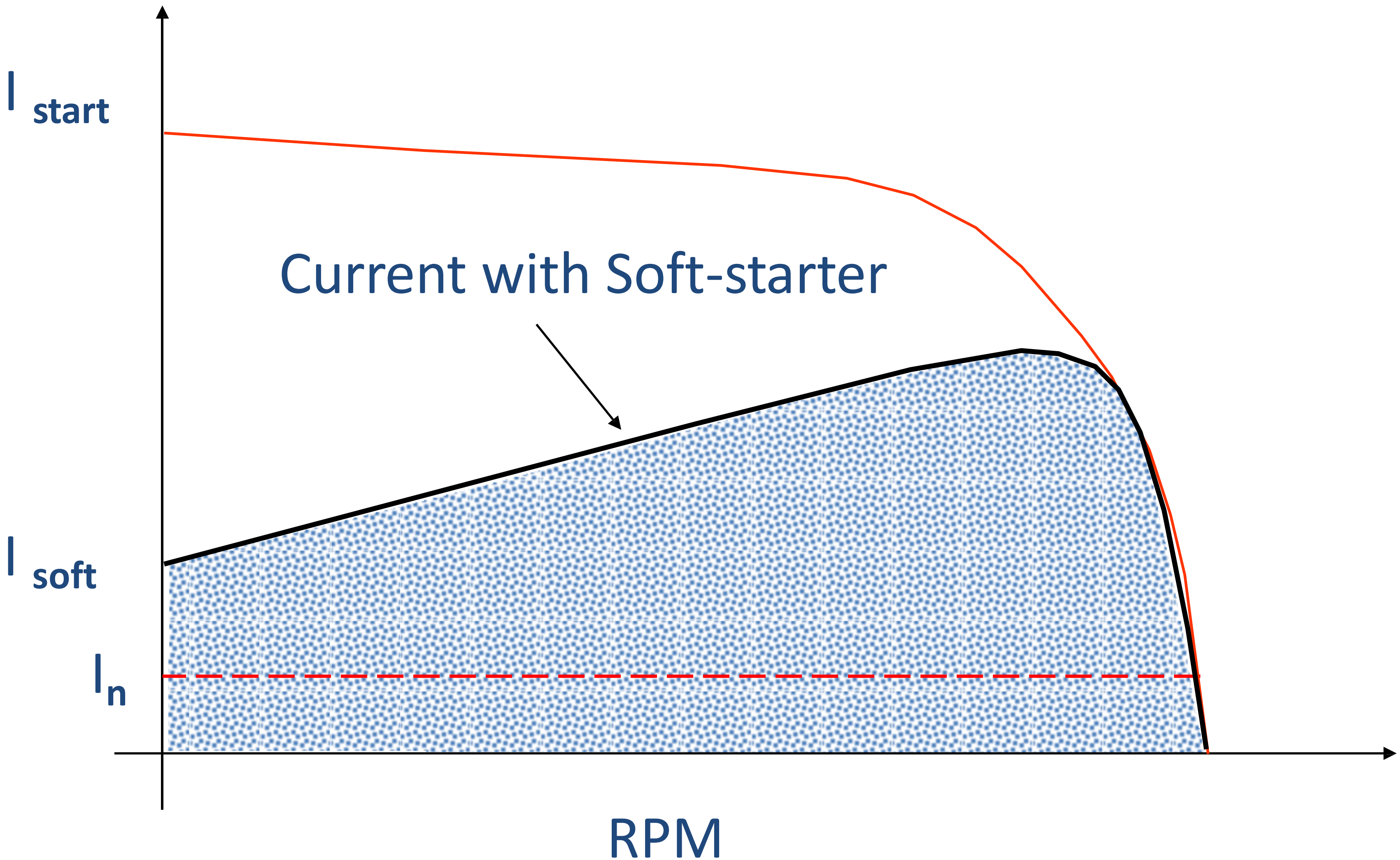


Voltage ramp-up (without Current Limit)



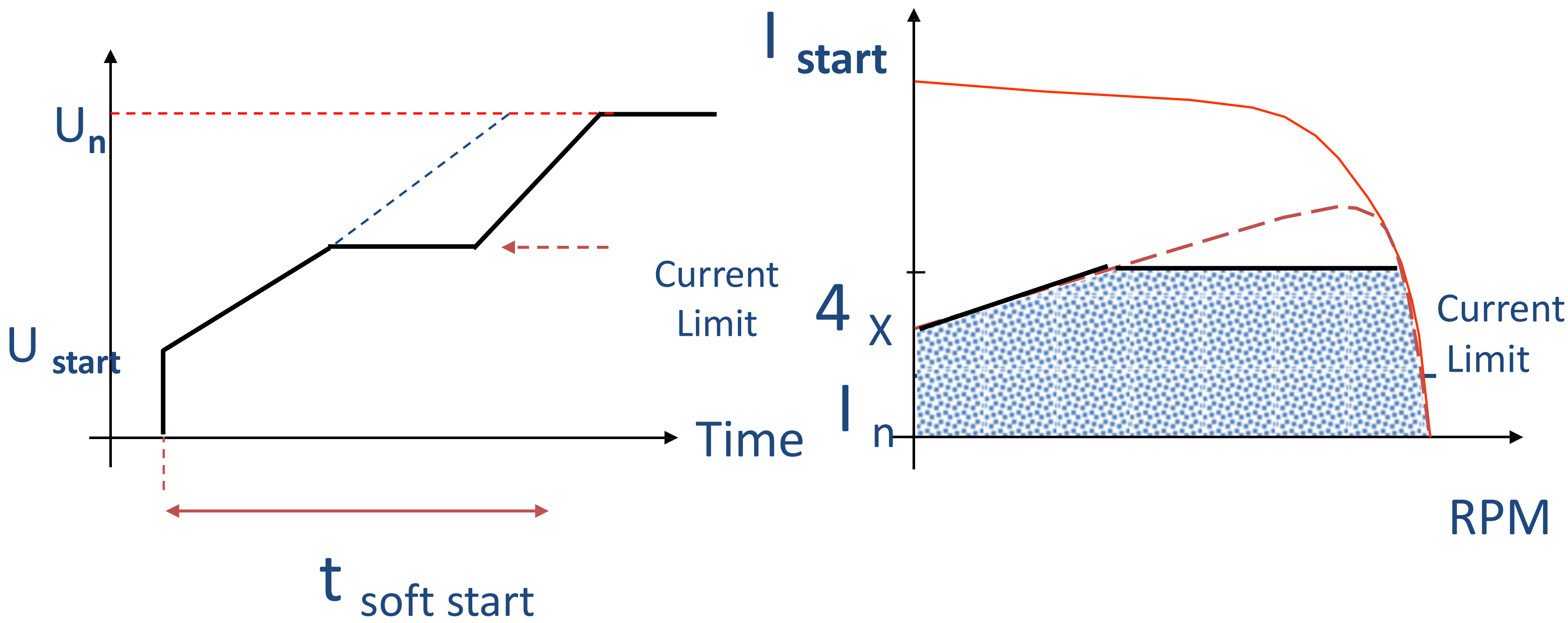
Soft Starters

Current Ramp-Up (without Current Limit)



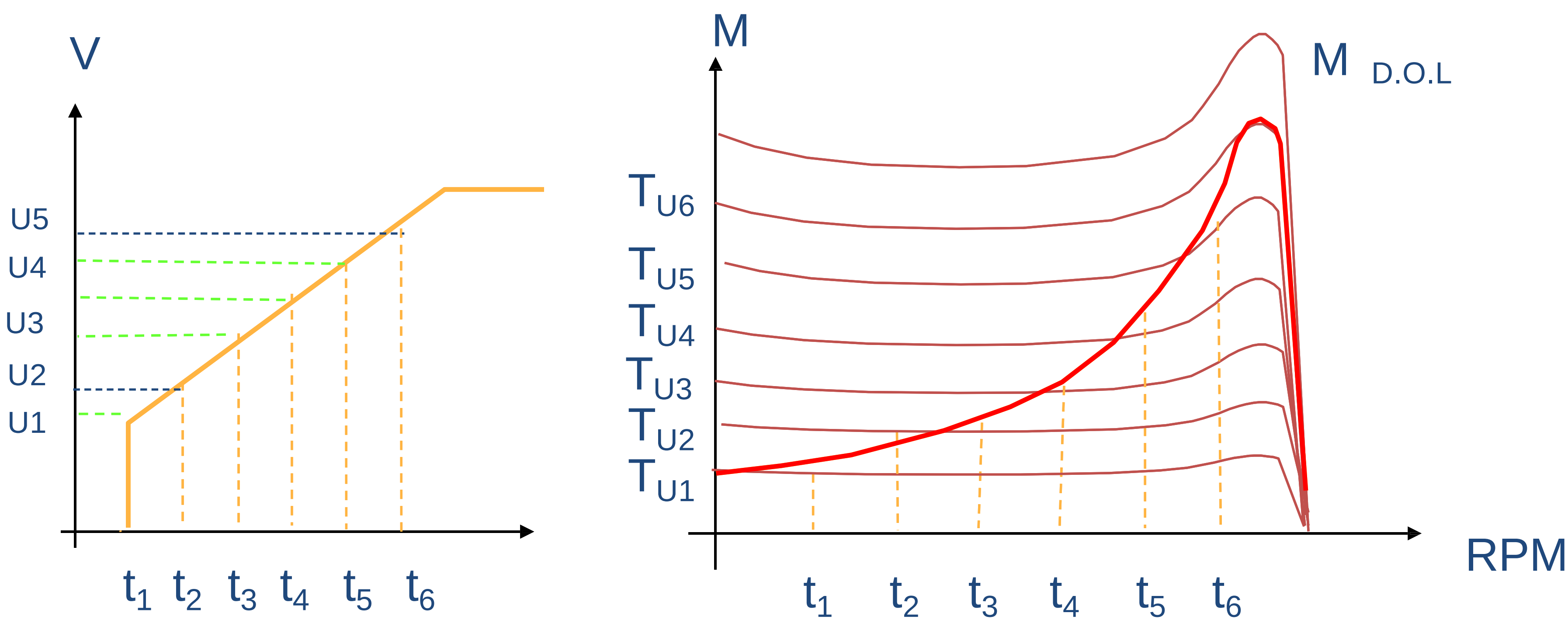
Soft Starters

Voltage & current increases until the current reaches Current Limit. The Voltage will not increase until current begins reducing, as the motor approaches nominal speed



Soft Starters

Motor Voltage / Torque Ratio



Soft Starters

Disadvantages:

- ✓Relatively expensive
- ✓Higher sophistication

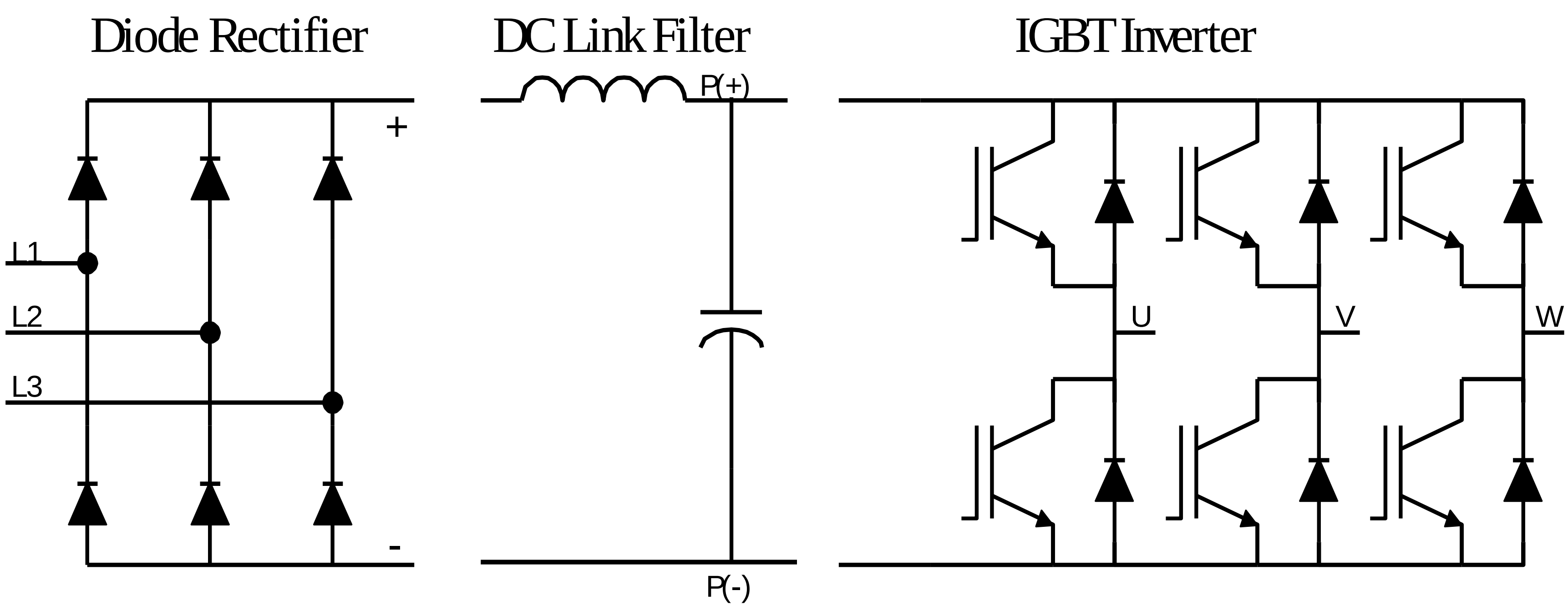
Advantages:

- ✓Solid state - no moving parts, less maintenance
- ✓Reduced starting current & mechanical shock
- ✓Smooth, step less acceleration & deceleration
- ✓Closed current loop starting
- ✓Easy adjustments for all applications
- ✓Comprehensive motor protection package

LV AC Drives

Consider the basic IGBT AC LV Drive - 6 pulse Drive

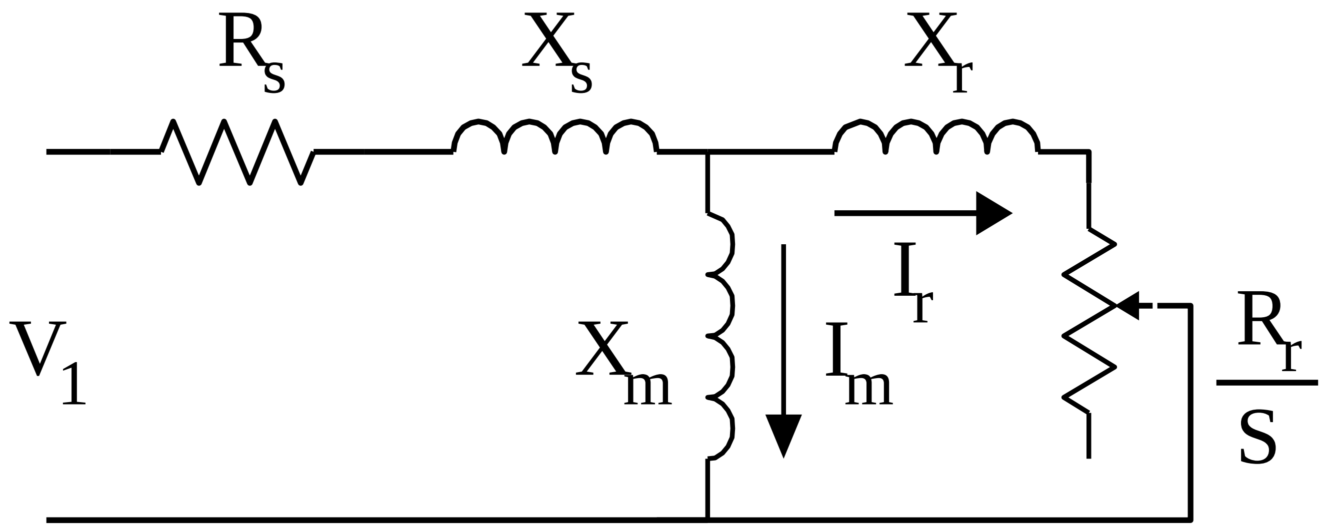
The Best in AC Motor Control! Torque & Speed Control



Basic IGBT Drive

Remember Torque?

- Torque is the product of magnetizing flux and rotor current
- Magnetizing flux is proportional to the transverse (mutual) current, I_m
- Rotor current is the current flowing through the rotor bars, I_r



Torque (T) ~ Air Gap Flux (F) ~ $(V/Hz)^2$

Now for Speed Control

The rotor speed depends on two things:

The rotational speed of the magnetic field is

$$n_0 = \frac{f \times 120}{p}$$

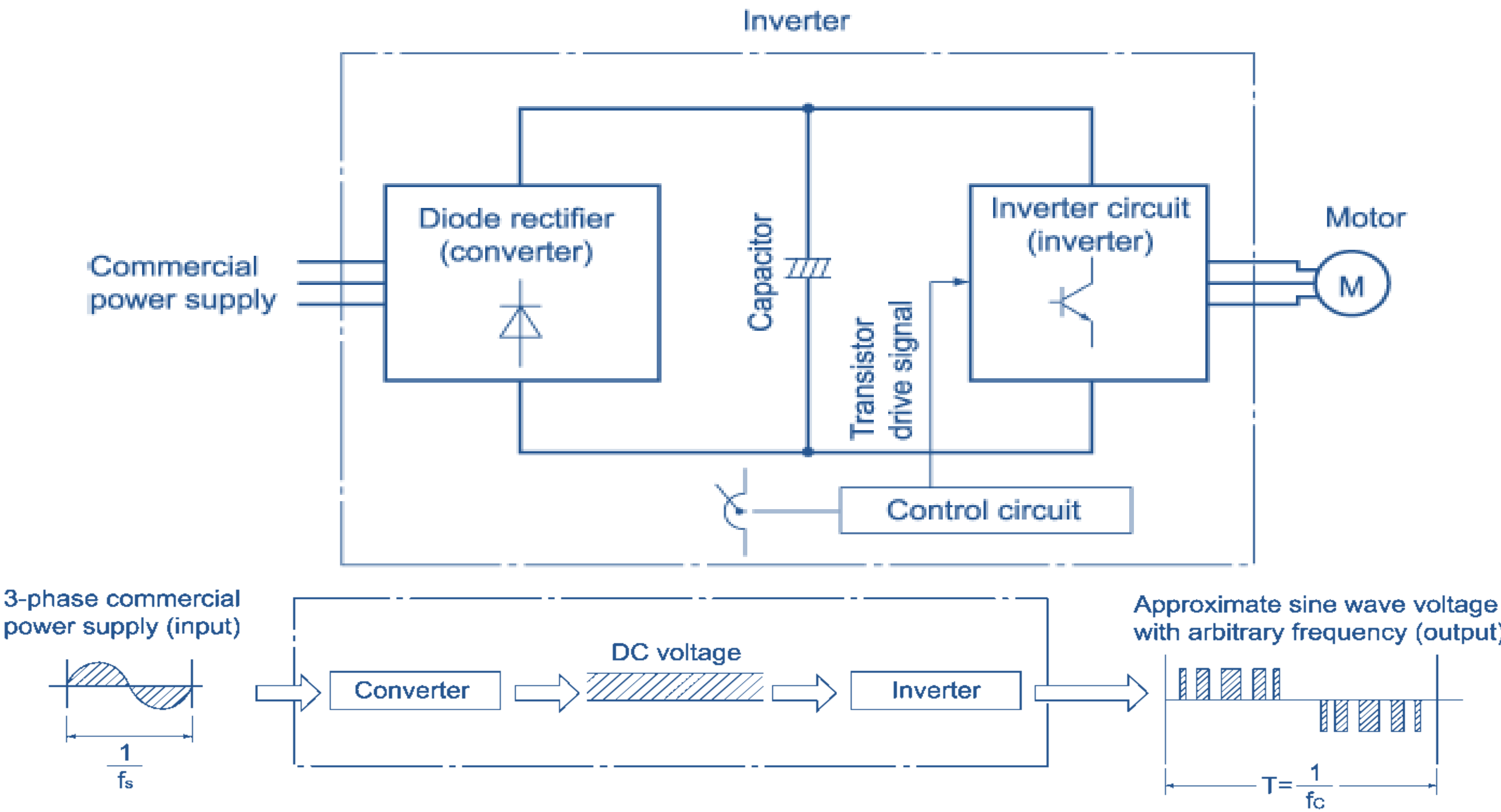
where f = applied frequency

p = number of motor poles

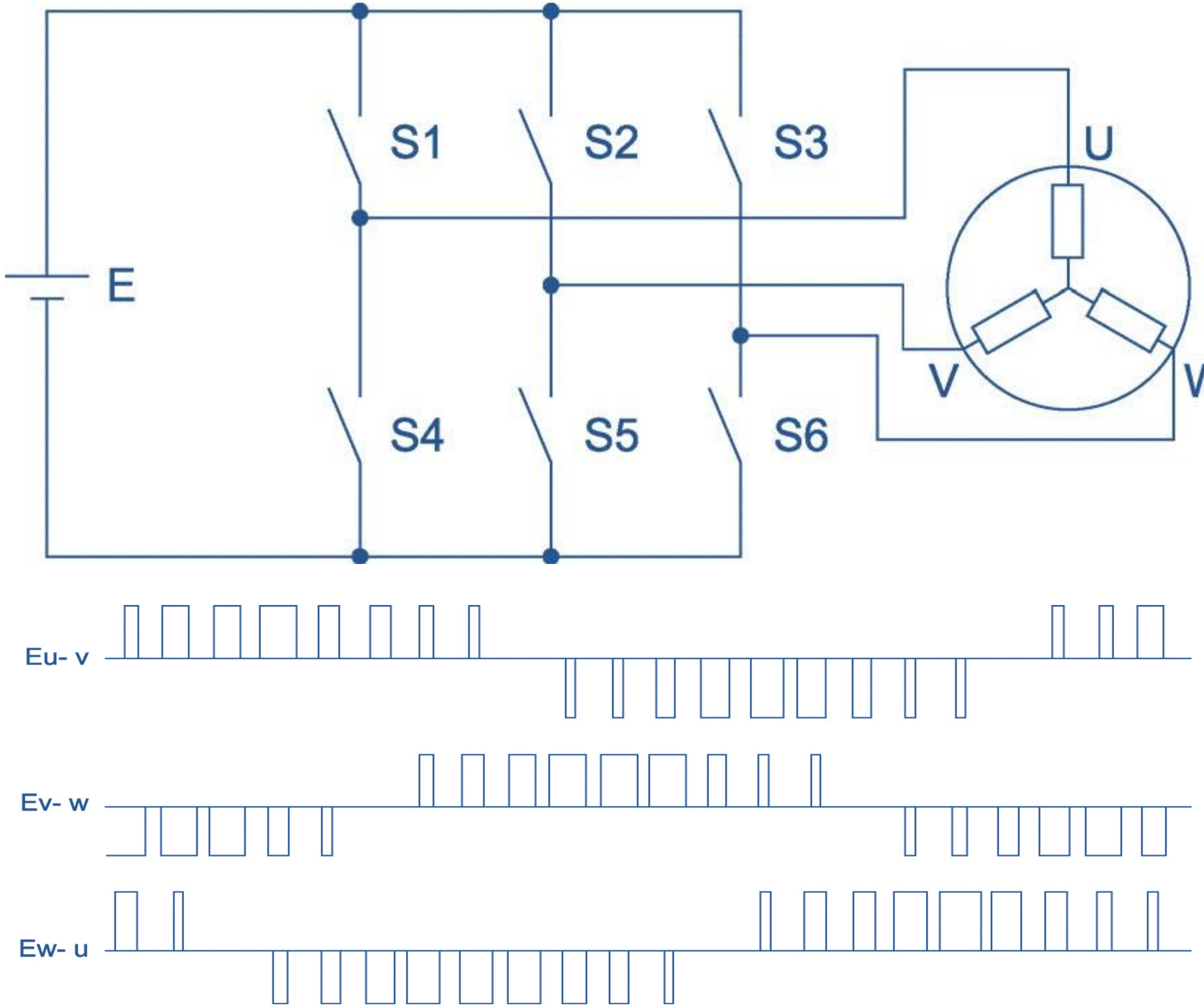
(for a 2 pole motor at 60Hz, n_0 = 3600 rpm)

(for a 4 pole motor at 60Hz, n_0 = 1800 rpm)

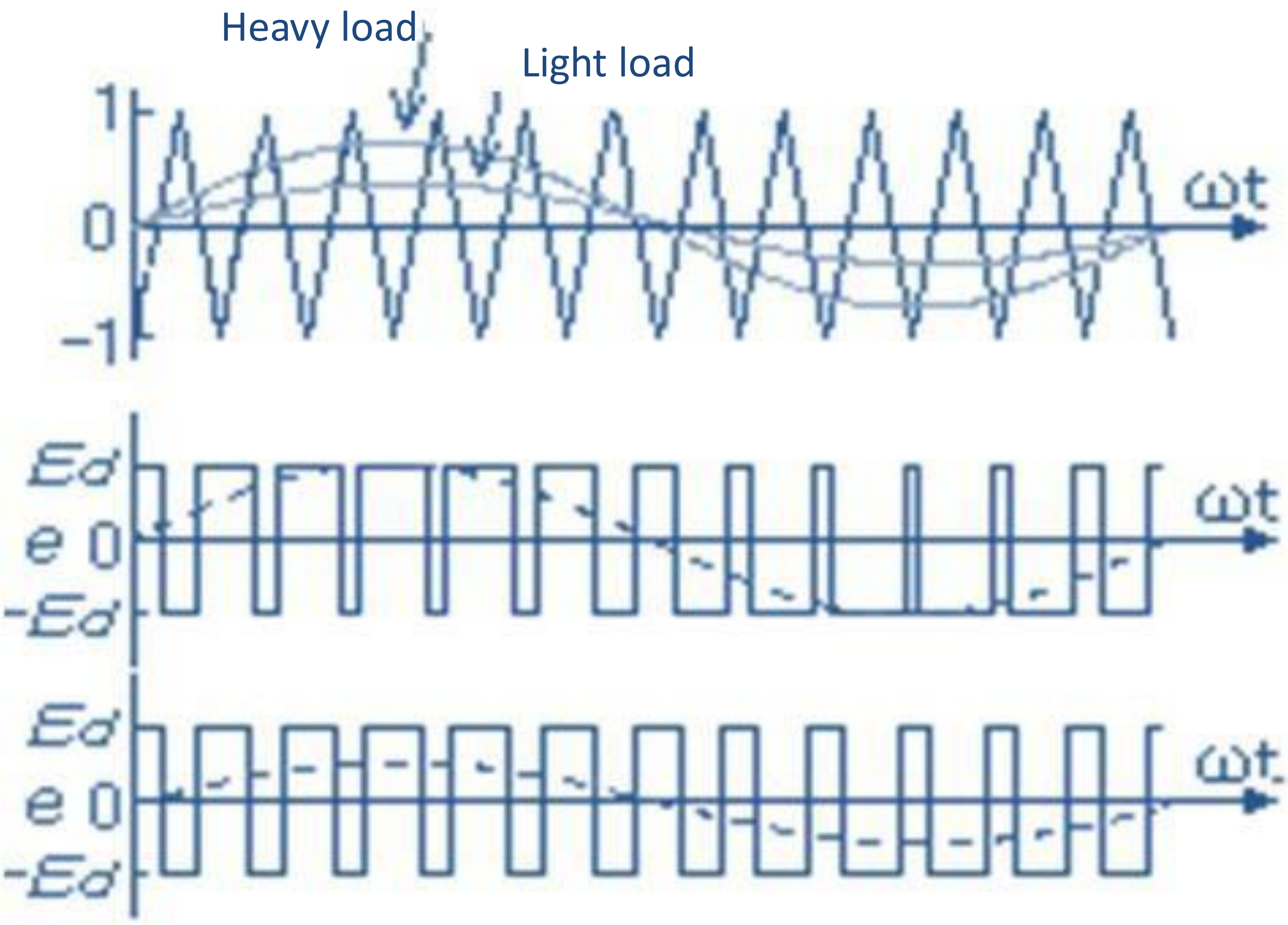
Operating Principles of AC Drive



IGBT   Switching



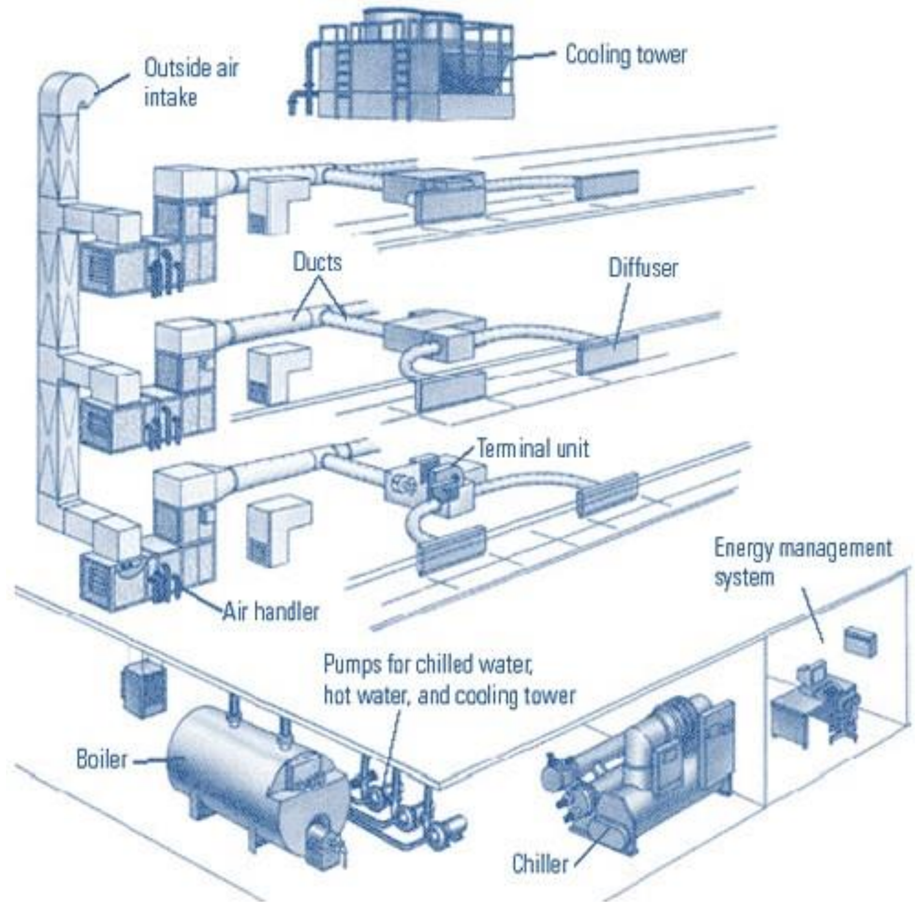
PWM Control



Why AC LV Drives

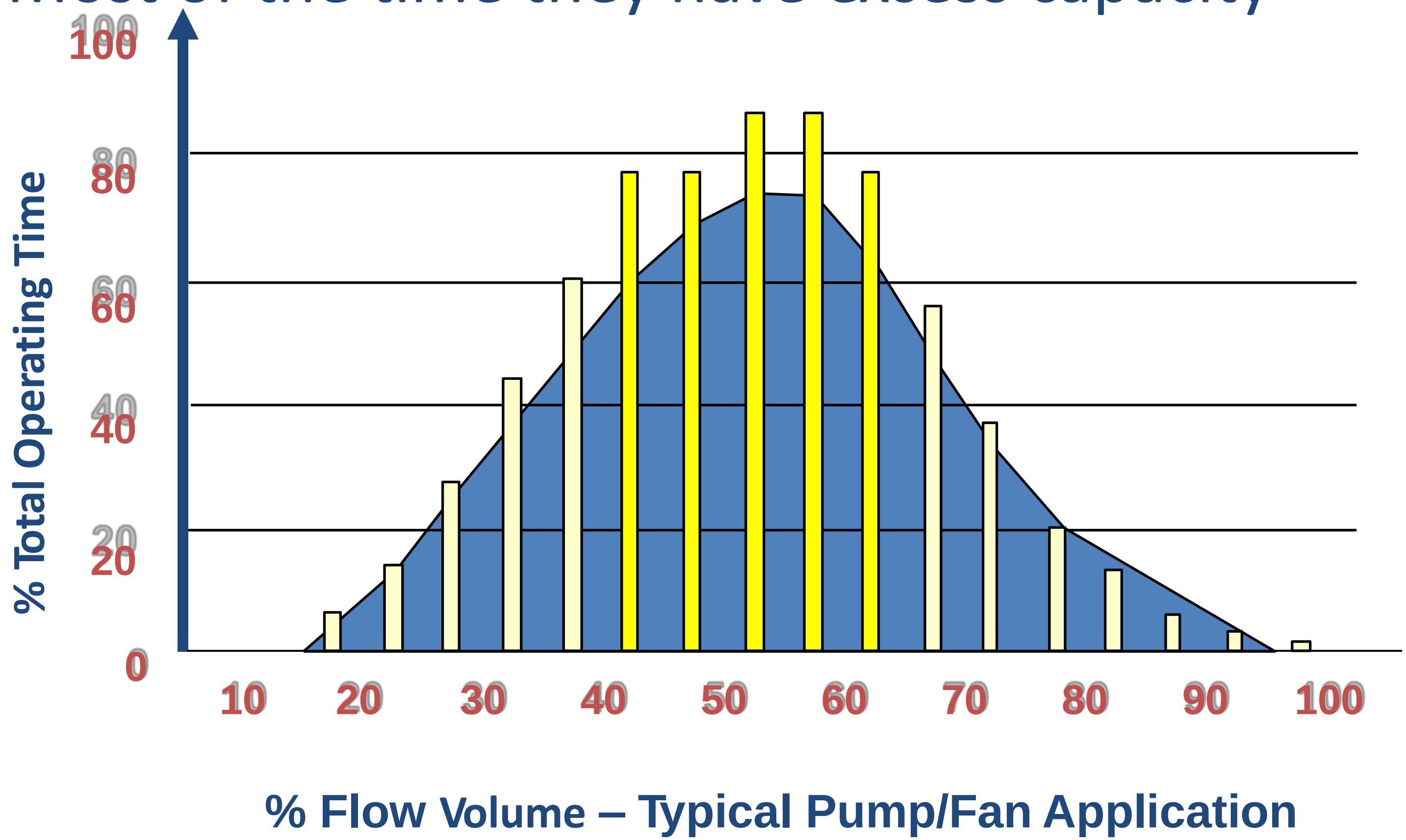
Energy savings

- Pump Systems alone account for an estimated 22% of the World's Electric Motor Energy Demand
- It makes sense to adjust motor operating speed to demands of the load. Would you regulate your car's speed with just the brakes?
- Varying load applications like centrifugal pumps and fans in particular benefit from ASDs. For example, when pump speed can be cut in half, resulting power consumption is reduced by a factor of eight!



Why AC LV Drives for Flow Control?

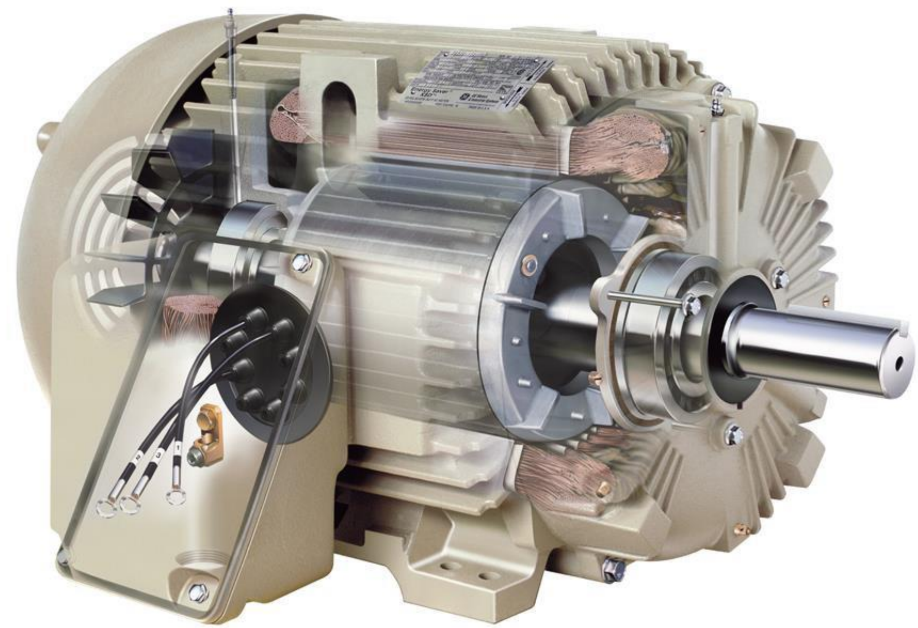
HVAC systems are designed for “worst case” situations. Most of the time they have excess capacity

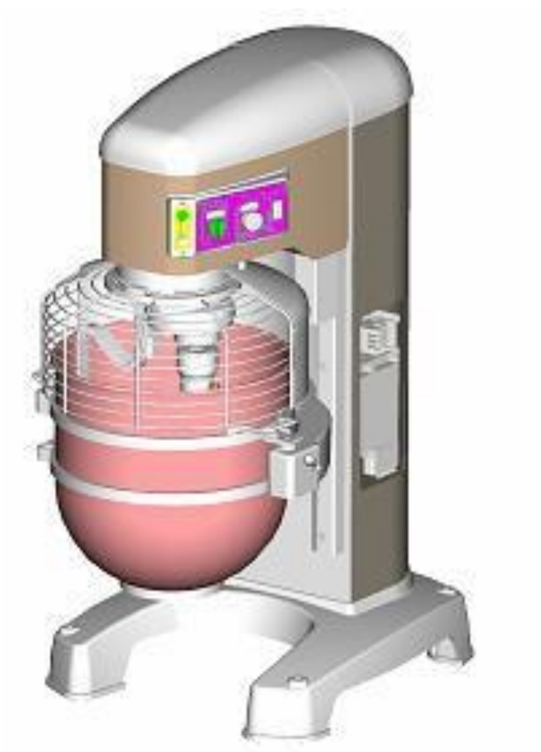


Why AC LV Drives

Process Improvements

AC Drives provide the right speed for the 'job,' allowing a production process to be optimized. Ability to easily make process changes increase productivity and increases Profitability

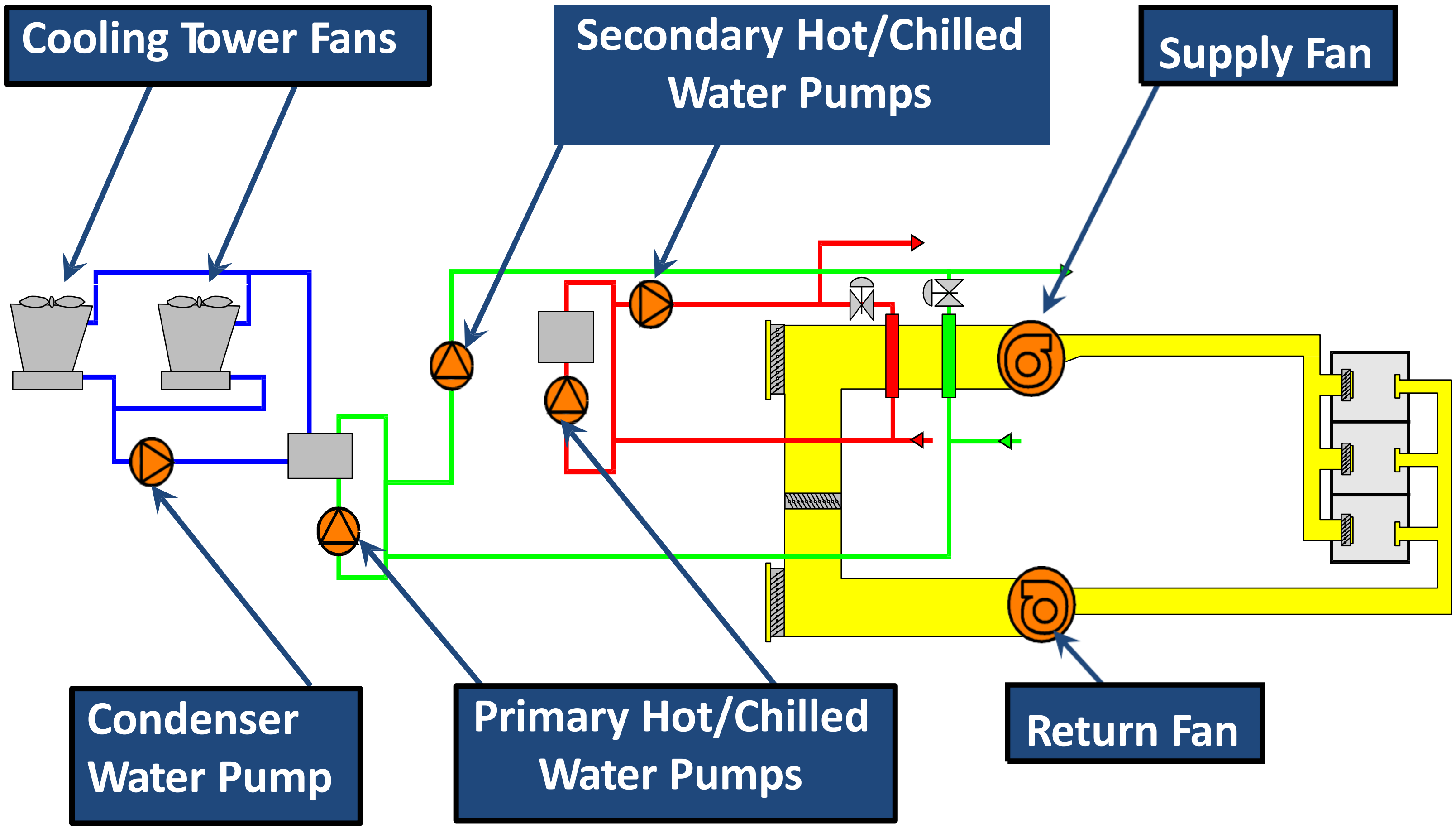




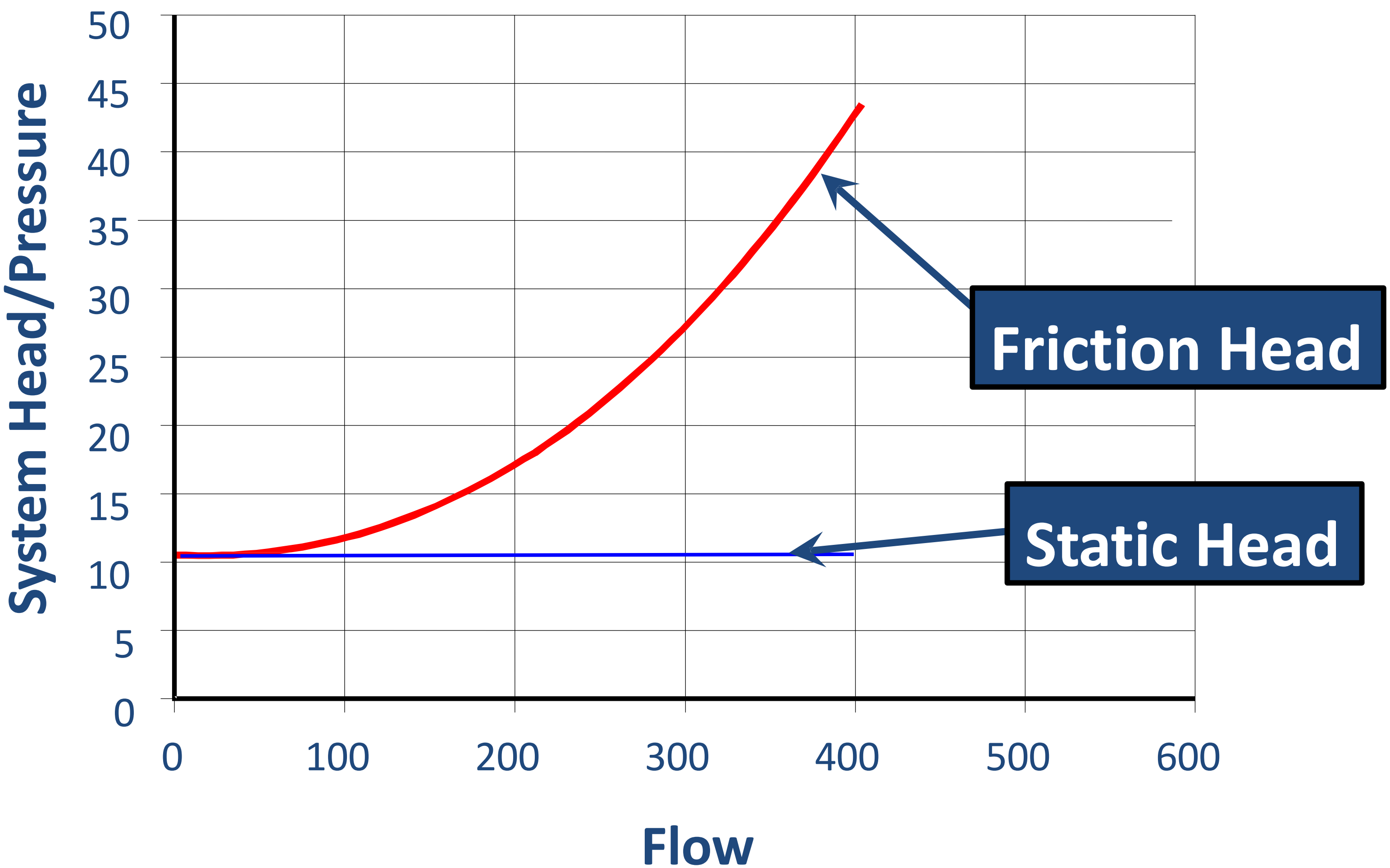
Decrease Machine Down Time

High starting currents of ac motors (6-10 times full-load amps) stress windings, generate heat, and shorten motor & machine life. AC Drives start at zero frequency and voltage, extending Motor & Machine life

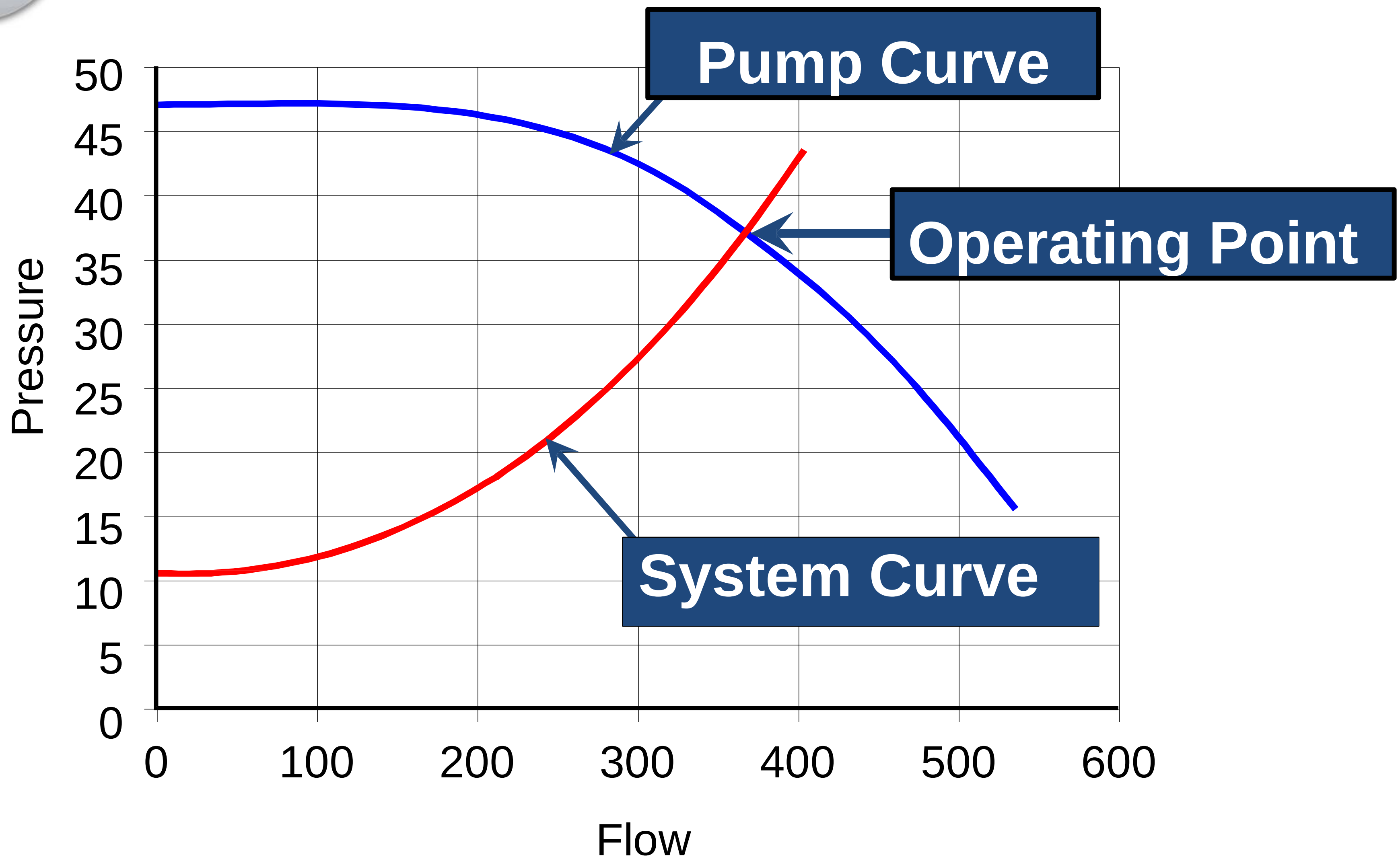
Opportunities Variable Torque Applications



Mechanical - System Curves

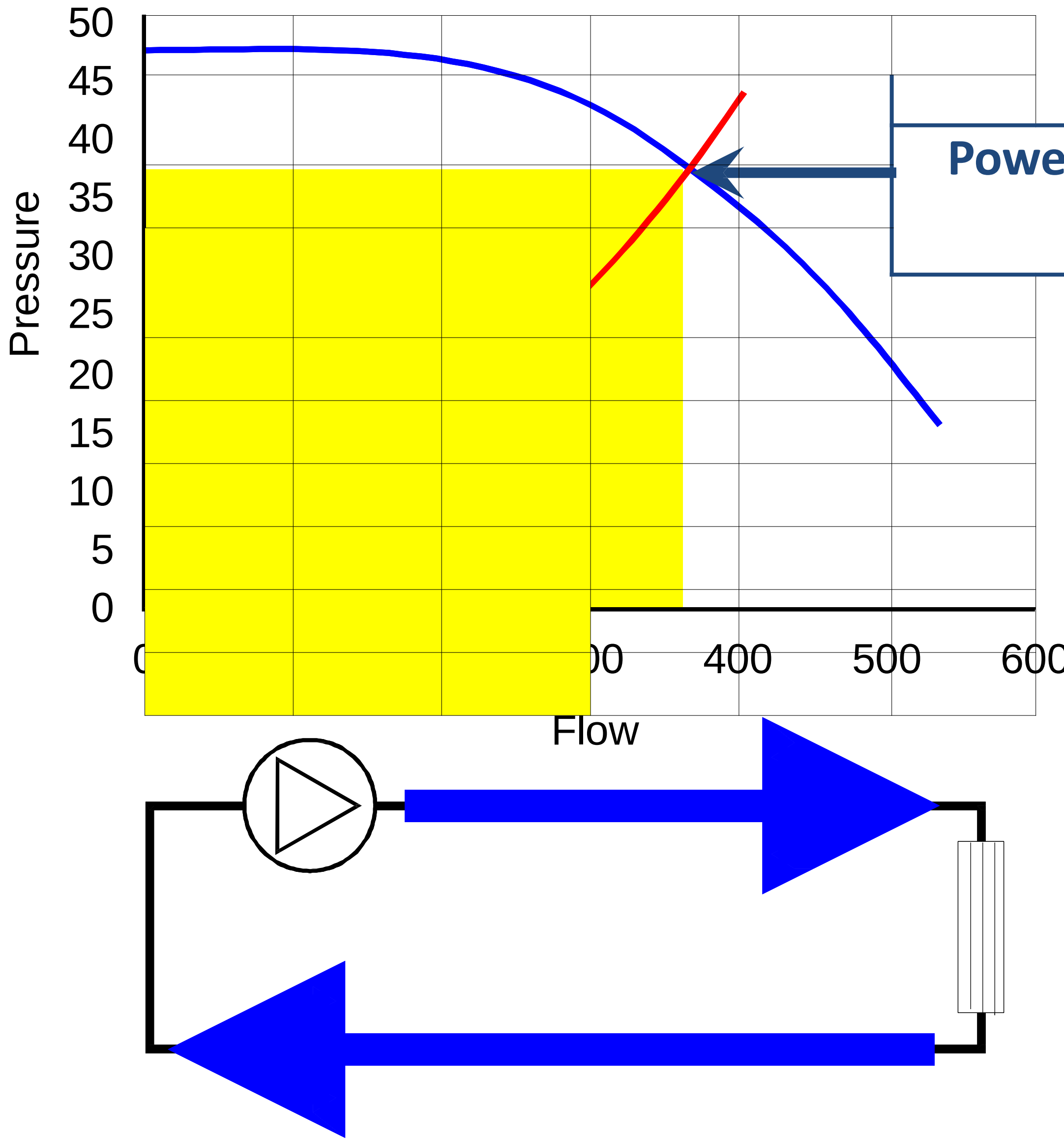


Mechanical – And Pump Curves



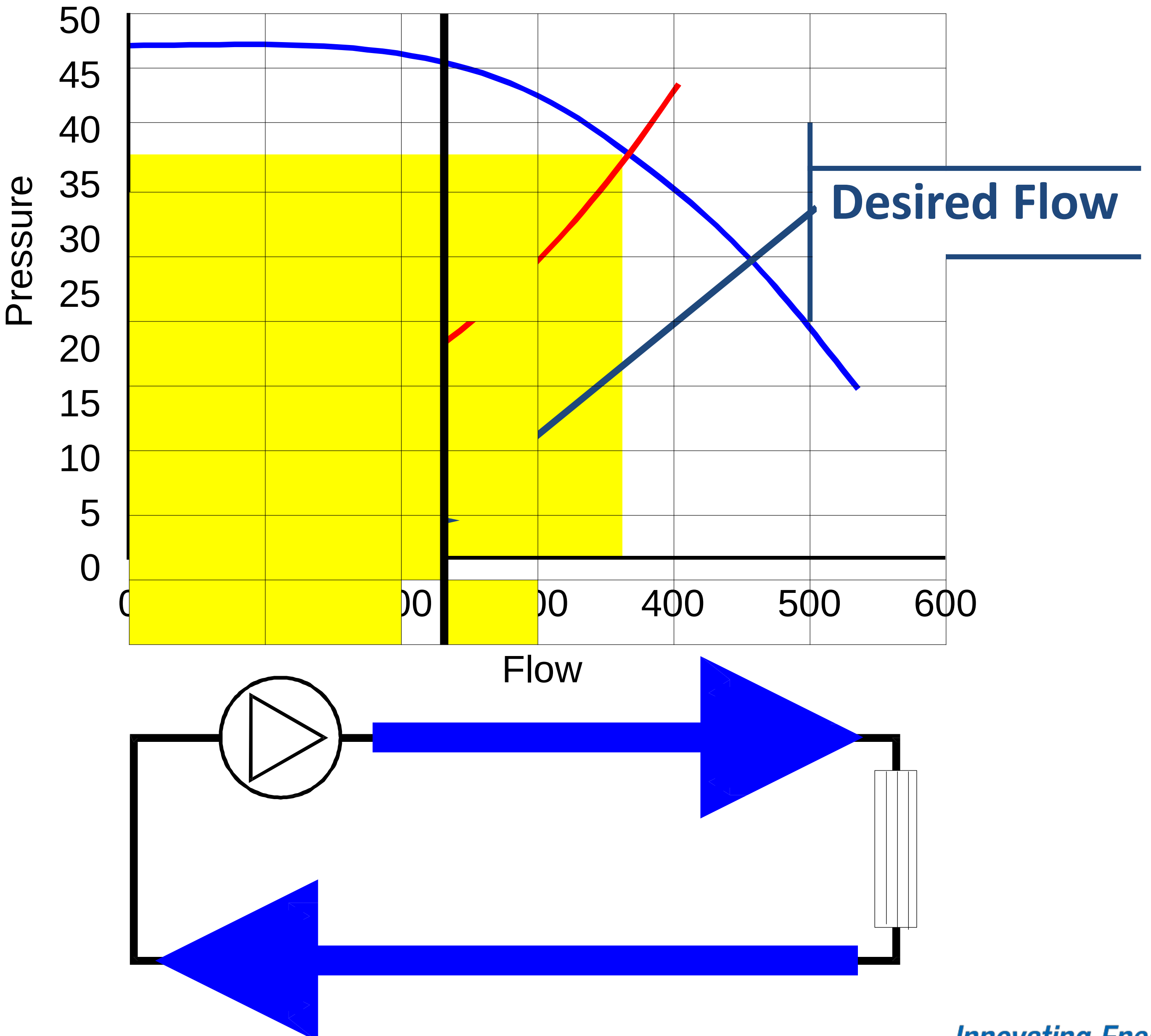
Fuji Electric

Energy Savings

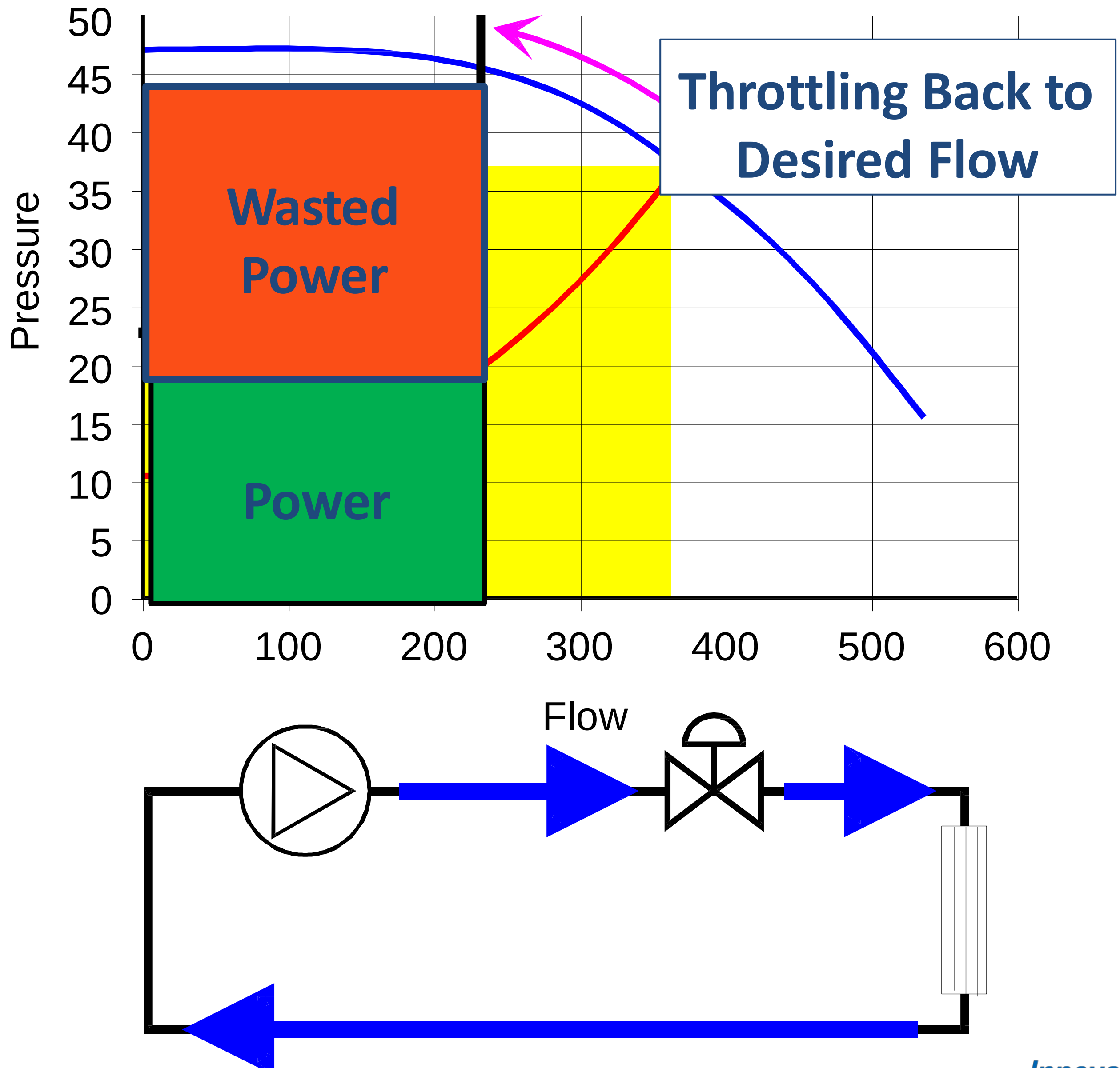


Power = <u>Flow x Pressure</u>
Constant

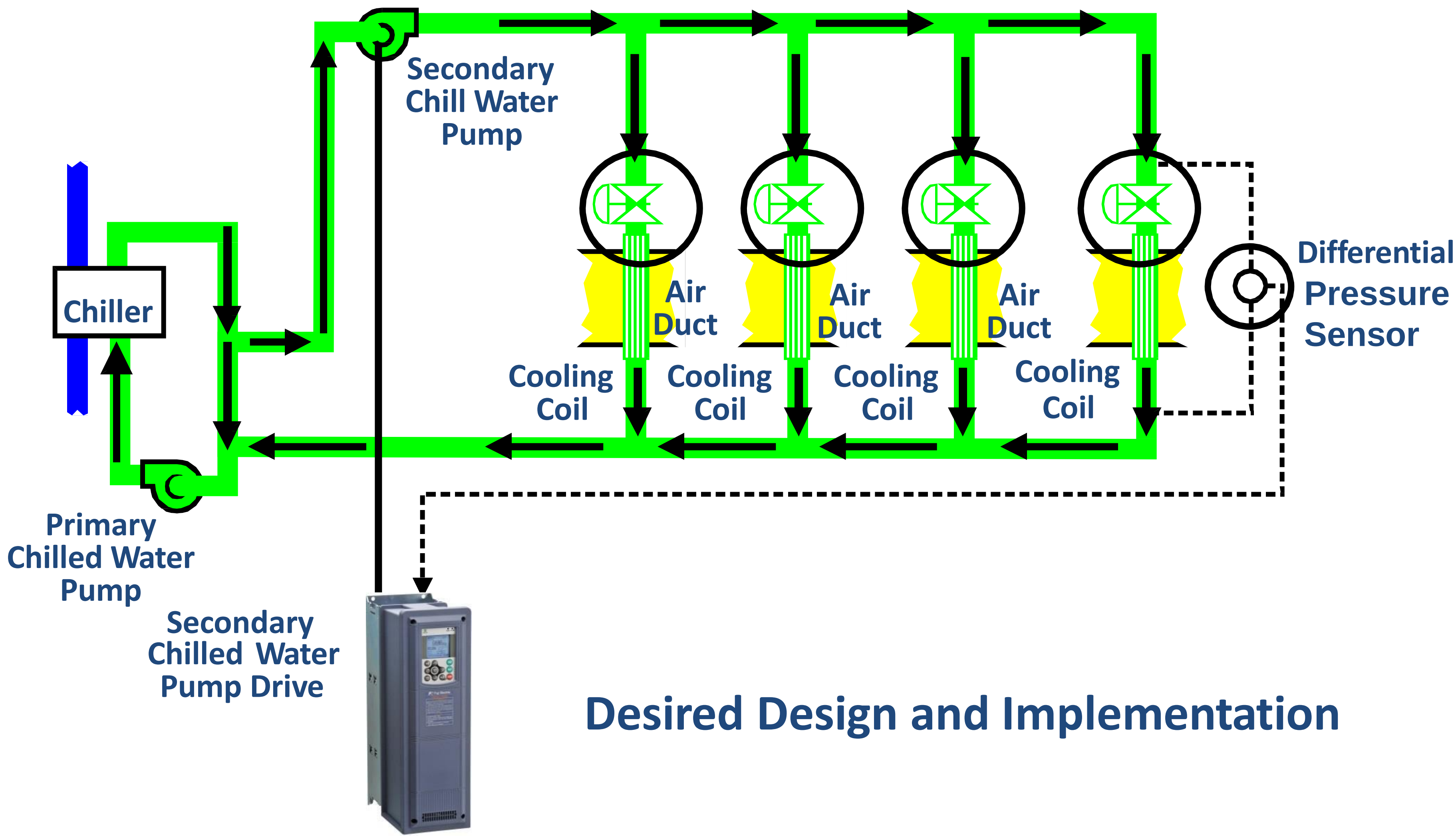
Energy Savings



Energy Savings – Throttling

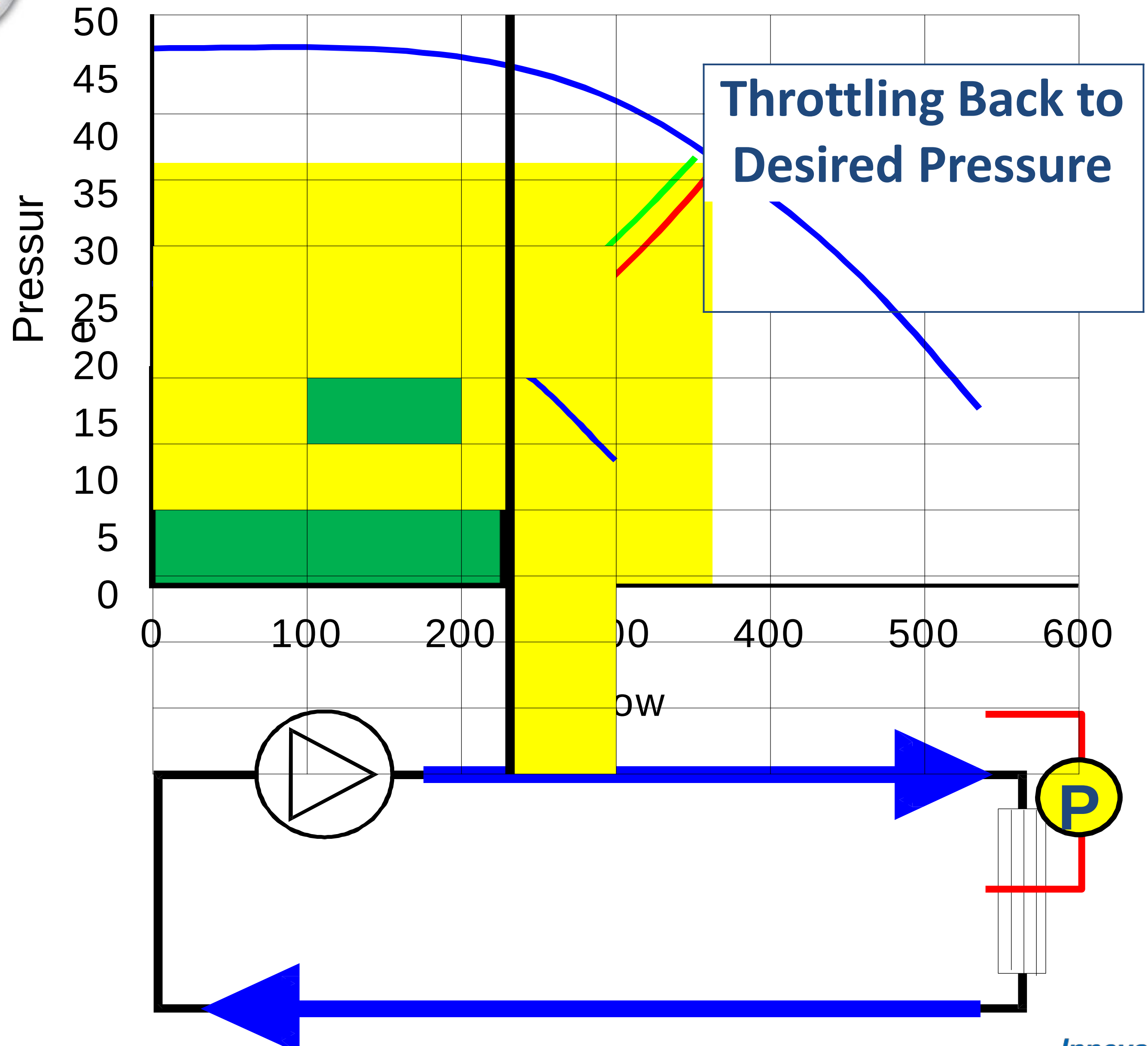


Controlling Secondary Pumps

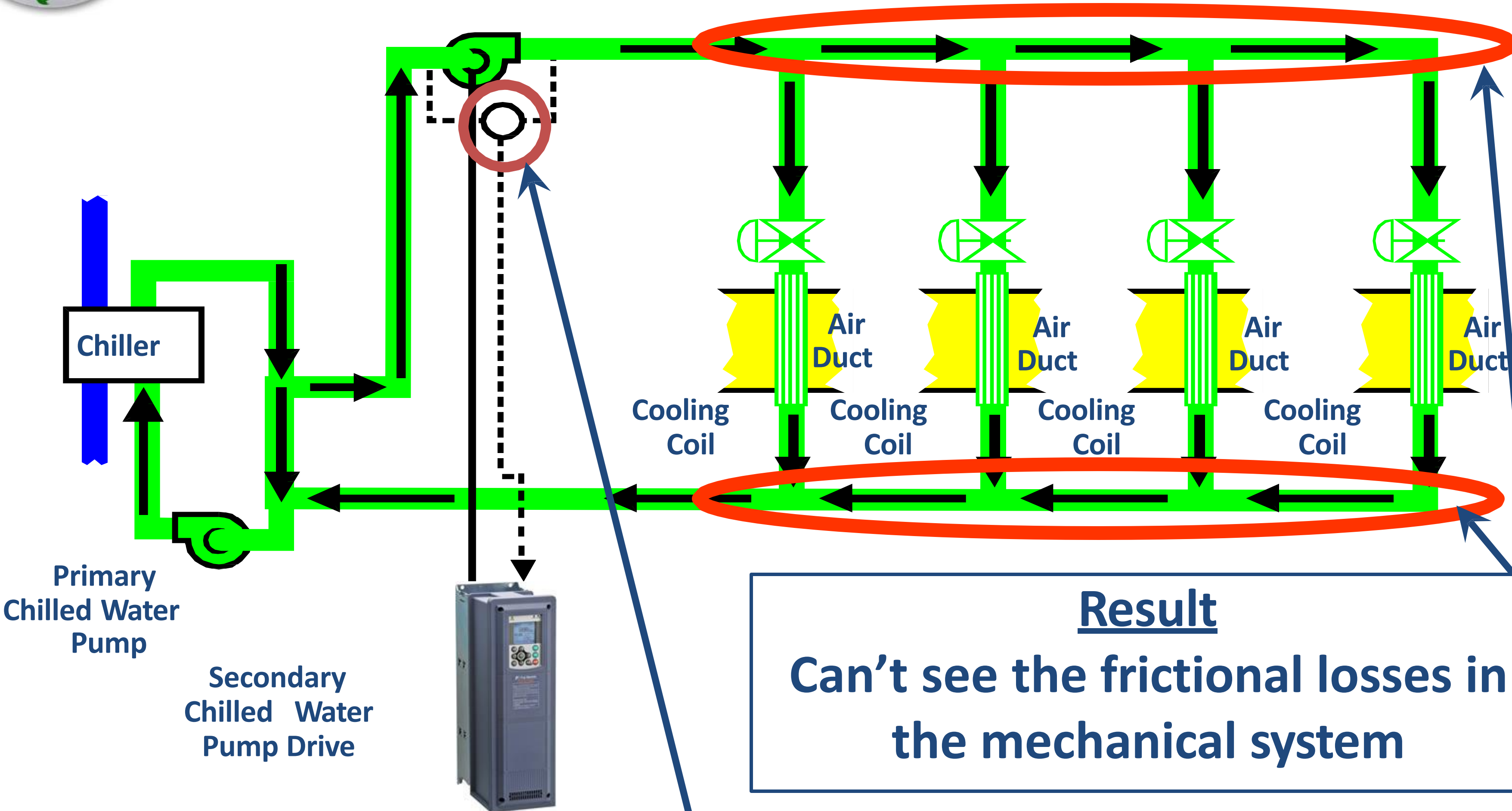


Desired Design and Implementation

Energy Savings – Adjustable Speed



Effect of Sensor Location

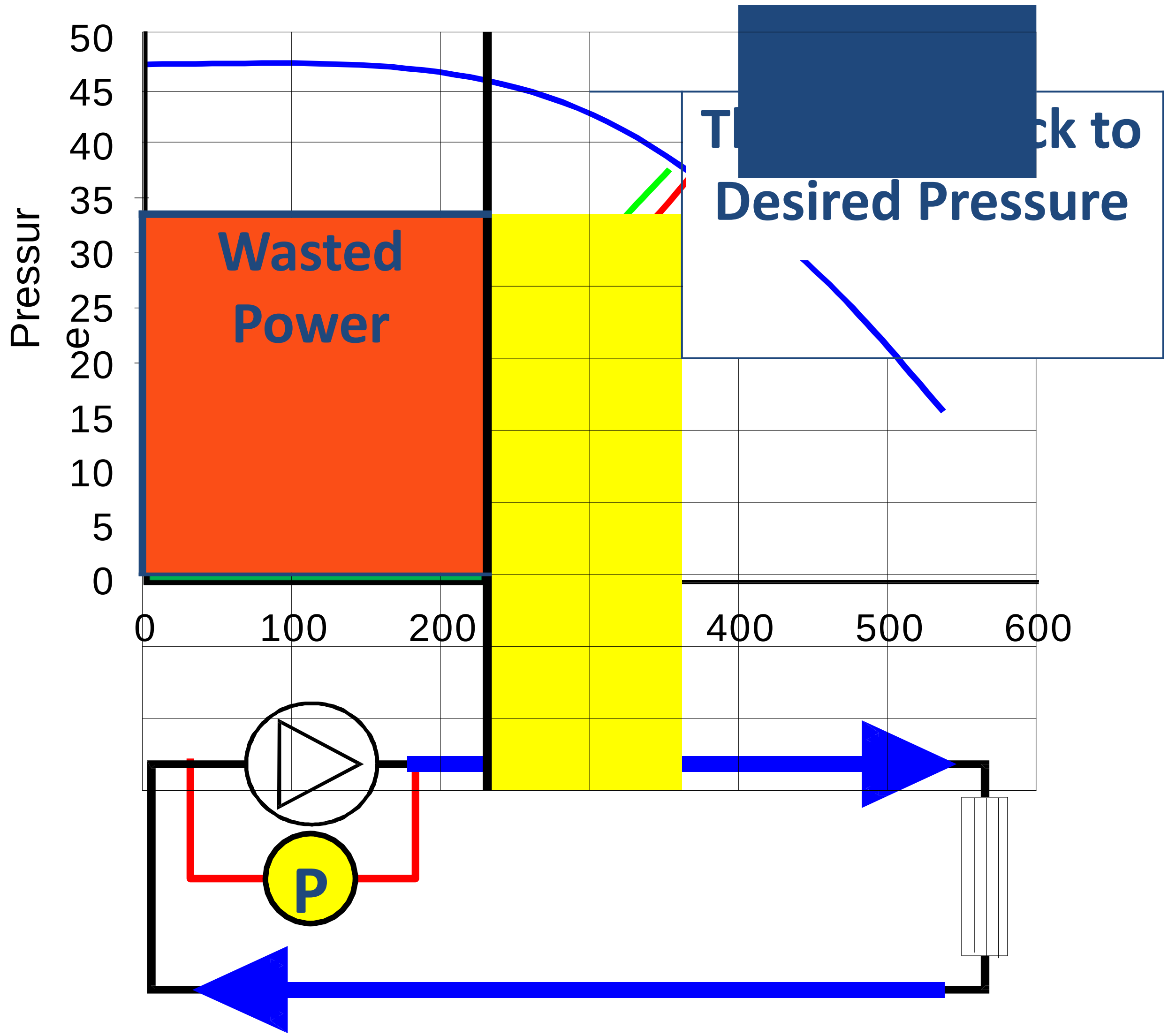


Result
Can't see the frictional losses in the mechanical system

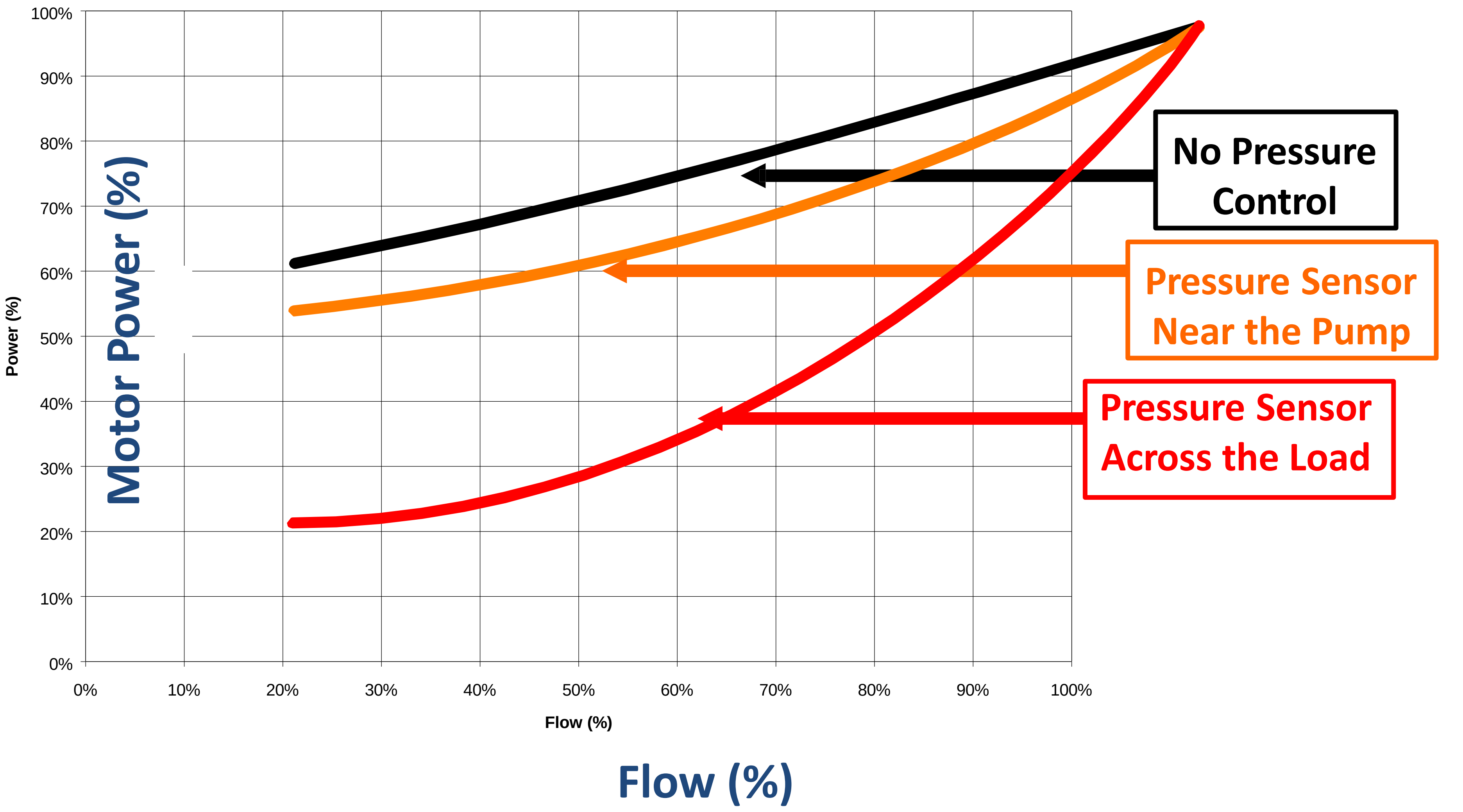
Typical Execution - Less expensive to put the pressure sensor here

Fuji Electric

Effect of Sensor Location



Effect of Sensor Location



Fluid Distribution System Protection

- Pipelines usually break because of too much pressure. If a pipe breaks, then there is a risk of pump damage: material losses around the break are also likely

- A pressure-sensing device to stop the pump avoids both of these possible outcomes. Pipeline protection can also be achieved by monitoring the pump output

- Adjustable Speed Drives mitigate the risk of rapid valve operation which is a leading cause of failures

Effect of Wear and Corrosion

The three main types of physical deterioration are:

1. abrasion
2. corrosion
3. cavitation

The rate of deterioration depends on:

- material type
- fluid quality
- temperature
- mechanical design
- maintenance schedule
- suitability of pump for the duty
- cavitation susceptibility

All of which are significantly Impacted by Pump Speed

LV AC Drives

Disadvantages:

- ✓Relatively expensive
- ✓Most sophisticated

Advantages:

- ✓Solid state - no moving parts, less maintenance
- ✓Reduced starting current & mechanical shock
- ✓Smooth, step less acceleration & deceleration
- ✓Speed & Torque Control
- ✓Comprehensive motor protection package
- ✓Special functions for Fan & Pump Control

Questions?

Thank you for your Time