ECE 528 – Understanding Power Quality

http://www.ece.uidaho.edu/ee/power/ECE528/

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Lecture 23

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Today: An introduction to industrial controls

- Basic hard-wired controls
- Common symbols and conventions
- Some examples
- Programmable Logic Controllers (PLCs)
- Power quality issues
- Incorporating Power Quality into control system design
- Reminder: Download and read Siemens STEP documents linked to on the class PQ links page or at the end of lecture 22's slides

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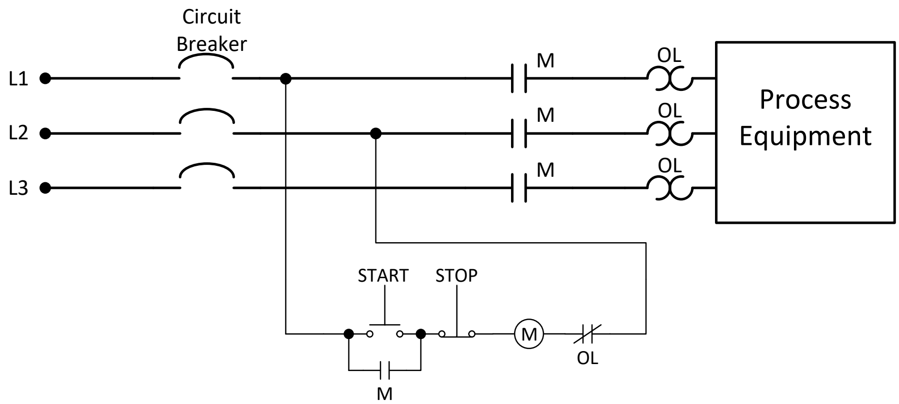
Some terms

- Process variable
  - What is measured: Temperature, flow, pressure, mass, concentration, voltage, etc.
- Set point
  - The target for the process variable
- Error
  - The difference between the set point and the value of the process variable
- Controlled output
  - What is varied to move the process variable value toward the set point

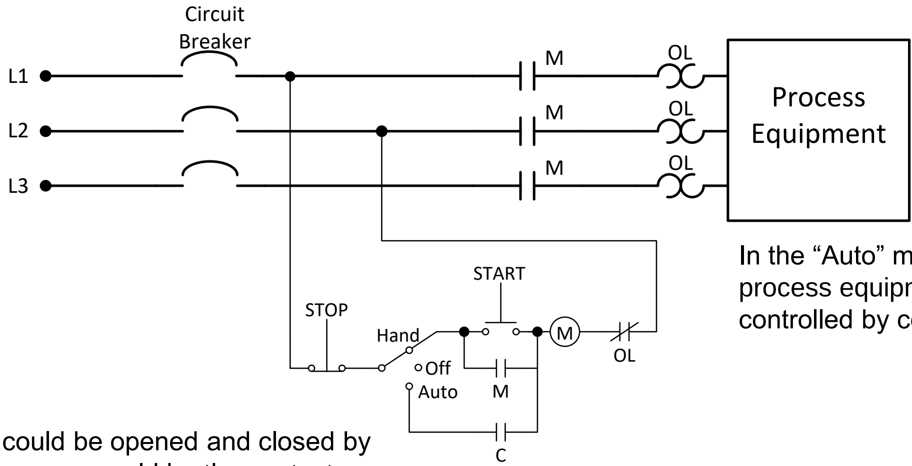
Important factors in industrial controls

- Factors affecting process control and the response of processes
  - Deadtime: the delay between a change to a control input and a detectable change in the process output
  - Gain: $\frac{\%\,output}{\%\,input}$ (may not be constant)
  - Inertia – mechanical, thermal
  - Changing environment
  - Changes in external processes
  - Change in process demand

A basic example – manual control



A basic example – automatic control



In the “Auto” mode, this process equipment can be controlled by contact “C”.

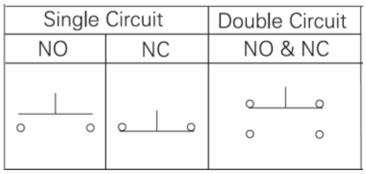
Contact “C” could be opened and closed by another process, or could be the contacts of a temperature switch, a level switch, etc.

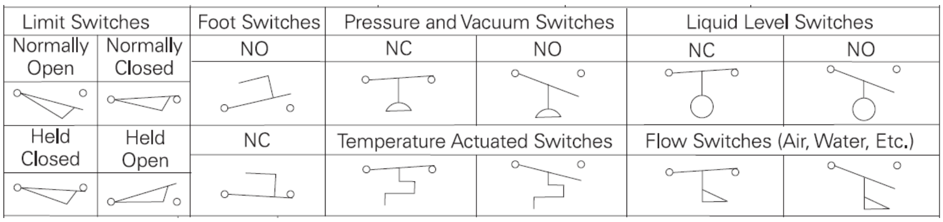
Common symbols – Switches

From Siemens STEP – Basics of Control Components

University of Idaho

- See IEEE-315/ANSI Y32.2 – “Graphic Symbols for Electrical and Electronics Diagrams”



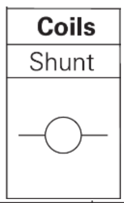


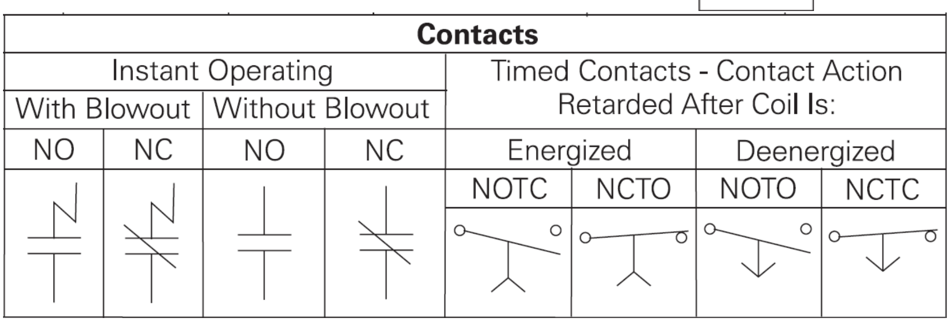
Common symbols – Coils and Contacts

From Siemens STEP – Basics of Control Components

University of Idaho

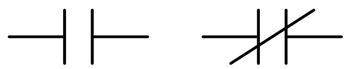
- Energizing coils operates contacts



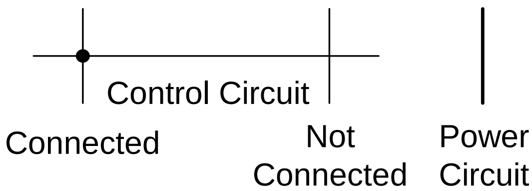


Conventions

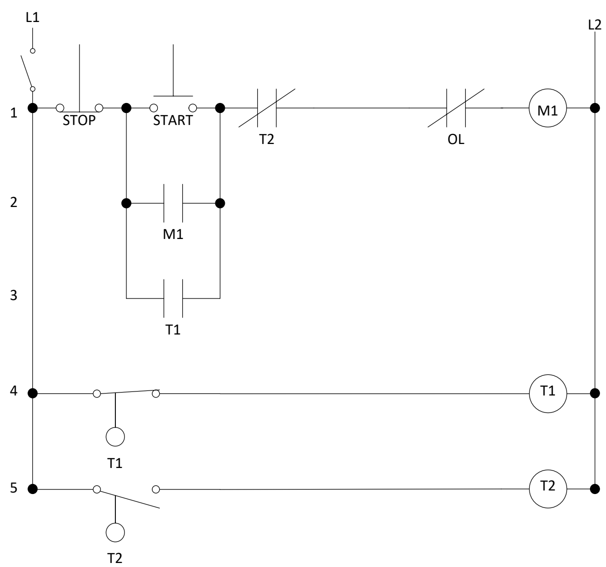
- Normally open/normally closed
  - Contacts are shown in their **de-energized** state



  - When their associated coil is energized, the contacts change state
- Line styles

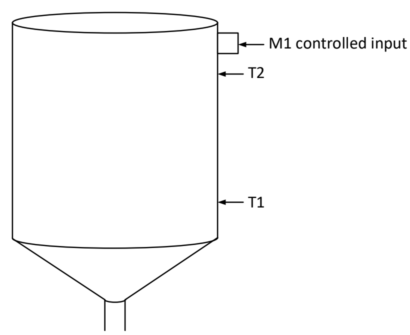


Ladder diagrams

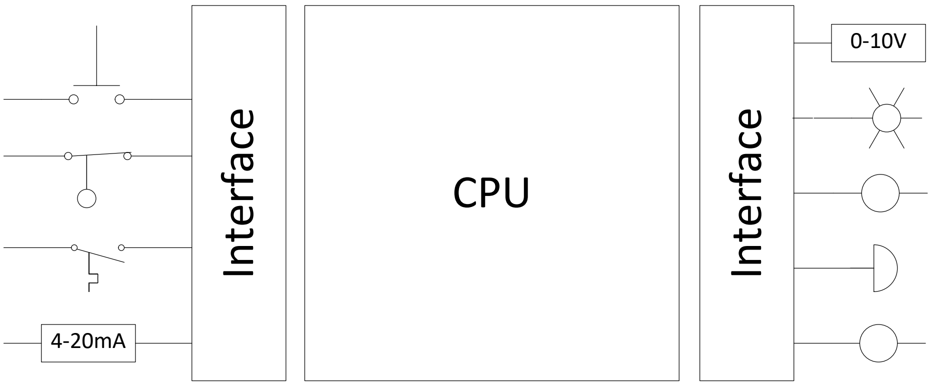


Ladder Diagrams

- Control voltage is connected to L1 and L2
- Common Control voltages
  - 120Vac
  - 24Vdc
  - Line-voltage



Programmable Logic Controllers



A Programmable Logic Controller

Power Supply

CPU

Input / Output

Picture from plcdev.com

Advantages of PLCs

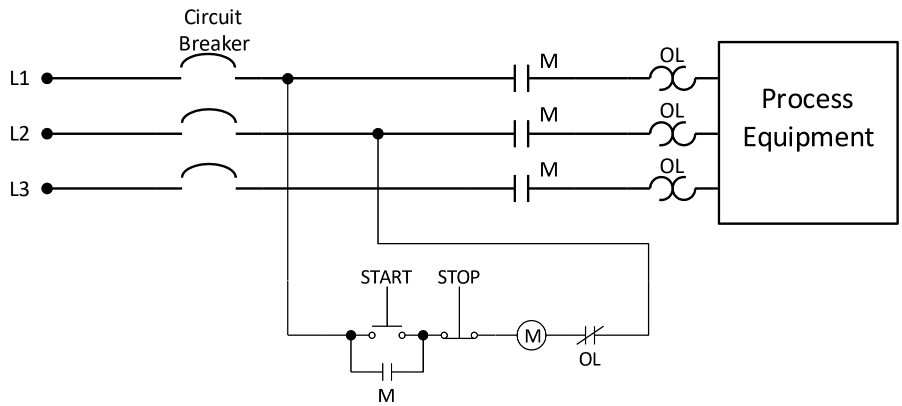
- Separate control relays are not needed – PLC can provide internal contacts
- Human interfaces can quickly be set up to provide process control functions and repurposed as process changes
- Allows quick changes to:
  - Setpoints
  - Process behavior
  - Relationships between inputs and outputs
- Allows for very complex process control

Control system vulnerabilities

- PLCs, relays, and contactors can be impacted by power quality disturbances
- Not all components are affected equally; some devices may trip during a particular voltage sag while other devices continue to operate normally.
- The result is loss of process control.

PQ is not always considered in the design

- Control system may direct process to operate when supply voltage is unacceptable

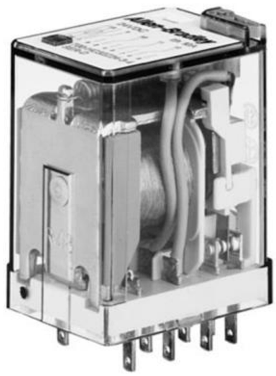


Power Quality objectives for control systems

- Reduce vulnerability of processes to power quality disturbances
  - Protect control system components
  - Keep control system operational during power quality disturbances
  - Prevent control system from operating equipment in unsatisfactory conditions
  - Let control system respond to PQ disturbances

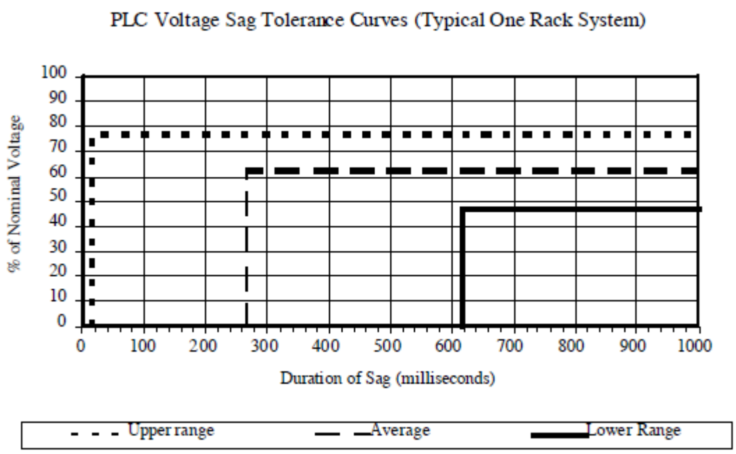
First step – identify vulnerabilities

- If available – portable sag generators can help identify “weak links”
- Use databases of equipment vulnerability (EPRI “PQ Investigator”)
- Common vulnerabilities
  - “Ice cube” relays are notoriously vulnerable to voltage sags
  - Other AC contactors may be similarly vulnerable
  - PLCs may trip causing a loss of process control



Picture from ab.com

Voltage sag tolerance curves



From IEEE Std. 1346

Protecting components

- Protection from physical damage during disturbances
  - Fusing to prevent damage during overloads or limit damage during faults in the control system itself
  - Surge suppression to prevent or limit damage during voltage transients
  - To the extent practical, locate control wiring away from power circuits
  - Consider inductive and capacitive coupling when routing control system wiring

Keeping control systems operating

- Specify voltage sag tolerance in design
  - SEMI F47 or other standards may be used
- Use DC–powered controls (with three-phase power supplies where applicable)
  - DC power-supplies provide inherent ride-through capability due to their capacitors used to filter the DC output power
- Match voltage specifications to supply
  - 240V equipment will usually run on 208V, but with less voltage sag ride-through

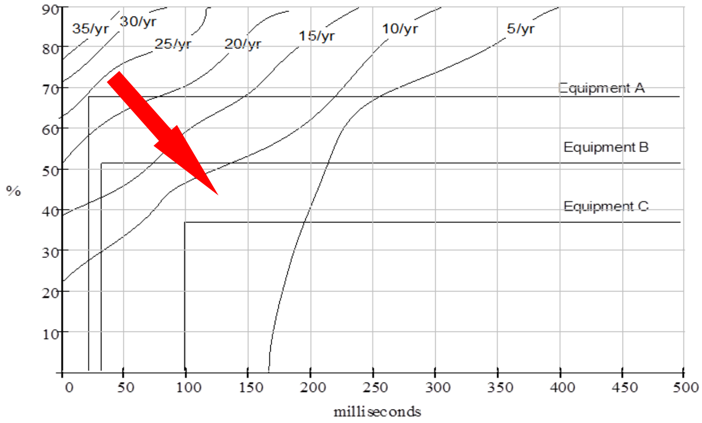
Keeping control systems operating

- Serve power supplies with a nominal voltage near the peak of their range
  - Increases energy stored in power supply's DC bus capacitors
- Power single-phase controls from line-to-line voltage
  - A single-line-to-ground fault will reduce control voltage to 58%, which may still be enough to operate the controls; especially if the controls are DC.
- Power AC controls with UPSs
  - UPS can provide ride-through for voltage sags and short interruptions.

Keeping control systems operating

- Don't overload power supplies
  - Remember homework 2's capacitor discharge problem?
  - Increased load on a power supply reduces its ride-through time – capacitor discharges more quickly
  - A lightly-loaded power supply operated at peak rated voltage will have significantly more ride-through time than a heavily loaded power supply operating on a lower supply voltage

Objective is to push the corner of the compatibility curve down and to the right



The entire system's voltage sag performance is determined by the weakest component.

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Making the control system "PQ aware"

- Relays are available that can provide input to the control system when different PQ disturbances occur.
- In a simple, hard-wired control system these relays may be used to prevent equipment from operating, or to shut the system down when the supply voltage parameters fall outside some acceptable range.

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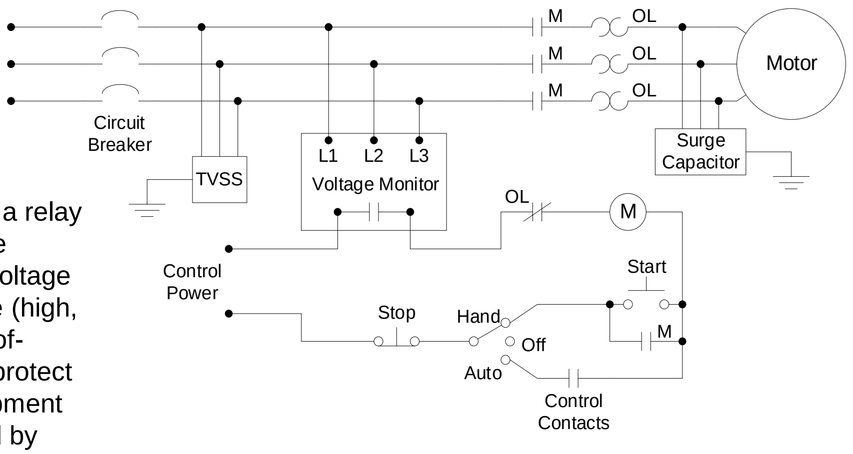
Making the control system "PQ aware"



The Voltage Monitor is a relay that will open and close contacts if the supply voltage becomes unacceptable (high, low, unbalanced, loss-of-phase, etc.) This can protect motors and other equipment that might be damaged by these conditions.

Making the control system "PQ aware"

- It may not be desirable to simply de-energize the controls during certain power quality disturbances.
  - Motors may ride through voltage sags
  - Variable speed drives can be programmed with "flying restart"
    - Detects motor speed and resumes programmed operation following a trip
    - No need to wait for the motor to coast to a stop first
  - Processes with thermal inertia are not likely to cool significantly during brief events

Making the control system “PQ aware”

- Conversely, if the controls stay “alive” they may direct the process to continue operating when the supply voltage is not compatible with the process equipment
  - Lost phase
  - Significant under or overvoltage
  - Phase reversal (very rare)

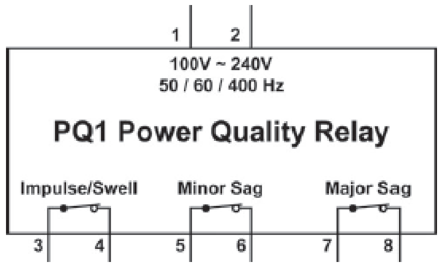
Making the control system “PQ aware”

- Some relay options – Voltage monitors
- Use adjustable thresholds
- Match thresholds to equipment tolerance
- Use output contacts as input to control system
- Design control system to respond in a desired way

Picture from ab.com

Making the controls "PQ aware"

- Power Quality relay
  - Opens different contacts based on event type
  - Thresholds are selectable



Pictures from powerside.com

Conclusions:

- Identifying control system vulnerabilities or "weak links," and making relatively minor changes to the control system can push the compatibility profile down and to the right, making the system less vulnerable to PQ disturbances.
- Keeping the controls "in control", adding power quality information to the control system, and designing the control system to respond to that power quality information can minimize the impact of power quality disturbances on processes.

Next time…

- Begin wiring and grounding
- Please read PSQ chapter 10