Electrical Troubleshooting

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Safety Is #1

Arc Flash Protection

Shock
Arc-Flash
Arc-Blast

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GFCI?

- Ground Fault circuit interrupter
- Trips on a difference of 4-6ma
- Where to you use them?
- Ext. cord has a Black, White and Green wire, Which one is the is the Grounded wire?
- What is a ground?
- Does lightning go from the ground up or from the sky down?

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Develop a Logical, Systematic Approach to Troubleshooting

1. **Confirm there is something wrong**
2. **Ask questions…..**
3. **Use your senses….**
4. **Gather your PPE**
5. **Get the prints or documentation**
6. **Test incoming voltage**
7. **Test outgoing voltage**
8. **Then Start in the middle**
9. **Find the problem or bad device**
10. **Remove the device**
11. **Test the device**
12. **Replace/Repair the device**
13. **Confirm the system is working correctly**
14. **Fix or order a new device**
15. **Complete Documentation**

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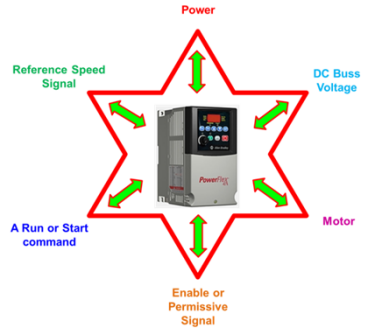
Troubleshooting VFDs

Troubleshooting Checks:

1. Supply voltage
2. DC Buss voltage
3. The motor
4. Enable or Permissive signal
5. Run start command
6. Speed reference signal



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Troubleshooting VFDs

1. Check supply voltage to the drive
   - ✓ Should not exceed drive rating by > 10%
   - ✓ Voltage spikes cause failure of SCR's, MOSFET's and power transistors, capacitors
   - ✓ May require a power line regulator
2. Check the DC buss voltage
   - ✓ On small drives use the touch pad
   - ✓ On large drives you can use your meter
   - ✓ On 480 drives the DC buss voltage should be around 670 volts

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Troubleshooting VFDs

3. Check the motor and its load

- ✓ Overheating can be the result of operation at slow speed – since the fan is turning slower
- ✓ May require external cooling fan
- ✓ Overheating may break down motor insulation – perform an insulation resistance test on windings

4. Enable or Permissive Signal

- ✓ Are all safety interlocks in the correct position
- ✓ What other equipment must be running before the machine can start (dust system)?

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Troubleshooting VFDs

5. Run or Start command

- ✓ What tells the drive to run (push button)?
- ✓ PLC (output)?
- ✓ Building automation system?

6. Reference Speed Signal

- ✓ Is it a voltage or a milliamp signal?
- ✓ From the touch pad or an external potentiometer?
- ✓ From a PLC or building automation system?

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Troubleshooting VFDs

Troubleshooting VFD's

Key Points

- You are troubleshooting an application, not just a VFD.
- Most people tend to over troubleshoot the problem, in turn causing new problems for themselves.
- Use all your senses in troubleshooting. (sight, sound, smell, hearing, and feel)
- Always use the manufacturer's manual during troubleshooting.
- Most accidents, on the job, occur while troubleshooting and repairing equipment.

Conditions Required for Proper Operation of VFD's

1. **Power**
2. **A Run or Start Command**
3. **Enable or Permissive Signal**
4. **Reference Speed Signal**

The steps needed to verify each of the four items varies from different manufacturers. The manual must be consulted for these steps.

Tips

- Never change two at the same time. Change one item at a time and see what effect it has. If none is noticed, put it back the way it was before making the change.
- If you remove more than one of anything (wire, card screw, etc.), label it or make a drawing of where it came from. A lot of time can be wasted trying to remember where it came from.

Troubleshooting VFD's (continued)

Tips

- If you make a measurement or take a reading, write the information down. This will prevent having to take the same readings again.
- Do not connect or install anything (fuses, circuit boards, wires, etc.) while the equipment is energized.
- Do not disconnect or remove anything (fuses, circuit boards, wires, etc.) while the equipment is energized.
- Do not jump out, disconnect, bypass, remove, or disable any safety device, fuse, breaker, or over current relay. During troubleshooting, you could make a mistake and short something out. Without the safety's or overcurrent protection devices, you have no protection.
- Never put more than one of anything in the equipment. If you replace a fuse and it blows a second time, locate what is causing the fuse to blow. Do not continue to replace circuit boards either.
- Just because a problem goes away, it doesn't mean that you fixed the problem.
- Never troubleshoot to destruction. If you think putting a piece of copper pipe or tubing, in place of a fuse, will help. You will be making a big mistake.
- When the little voice in your head tells you, "you have got nothing else to try", stop all troubleshooting actions. When there is no plan of action in troubleshooting, you place yourself in a position in which you can get hurt or potentially destroy the equipment.

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Troubleshooting Programmable Logic Controllers (PLC's)

Do you know what your lights mean?

LED,s Provide status indication and help with troubleshooting

- **Different manufacturers and models use different indicators.**
- **Let's look at a few common ones**
- **Refer to your PLC manual for specifics on yours**

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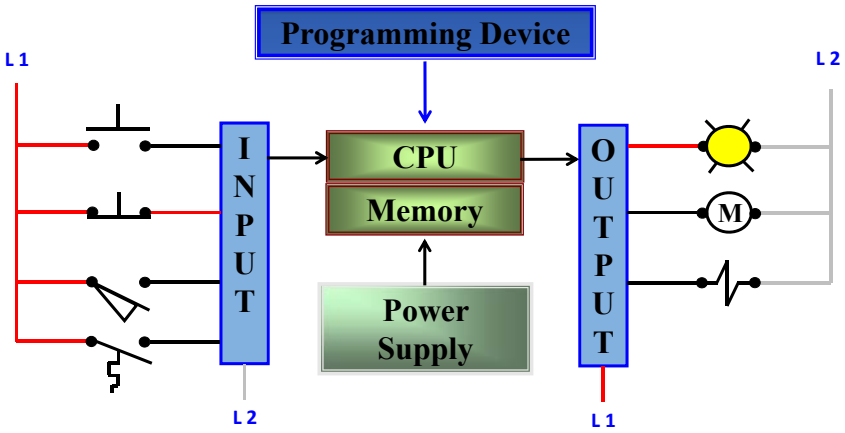
What is a PLC?

Do you know the 5 parts to a PLC?



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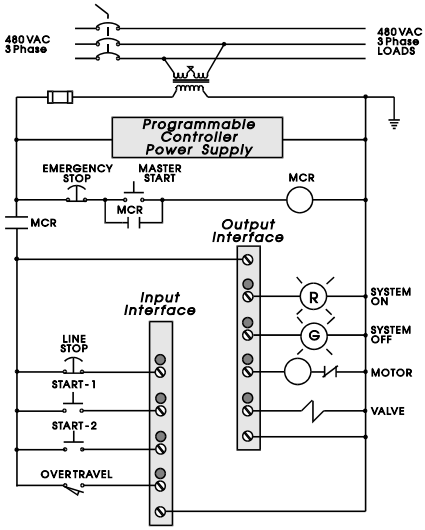
Typical Power wiring for PLC I/O



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Do you know what your lights mean?

Light	Status	Symptom
"RUN"	Steady	Good – Processor in Run Mode
(green)	Blinking	Transferring program from RAM to memory module
	Off	Not in Run Mode
Light	**Status**	**Symptom**
"FLT"	Off	Good
Fault	Blinking	At power up; processor not configured
(red)	Blinking	Hardware/Software fault
	Steady	Typically Processor Fault

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Do you know what your lights mean?

Light	Status	Symptom
"FORCE"	Off	No forces selected or enabled
(amber)	Blinking	Forces selected; but not enabled
	Steady	Forces enabled
Light	**Status**	**Symptom**
"BATT"	Off	Internal Battery Good
Battery	Blinking	At power up; processor not configured
(red)	Steady	Replace dead battery

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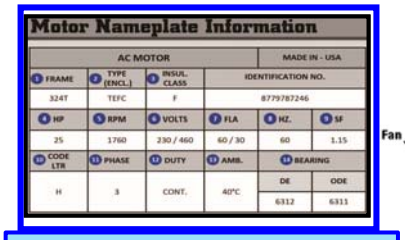
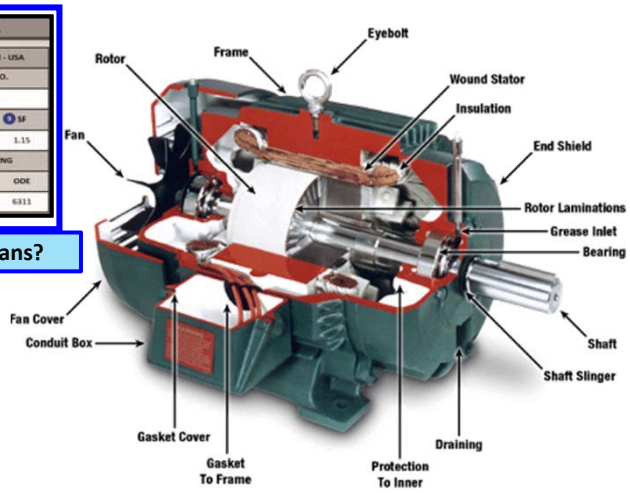
3Ø AC Induction Motor



Do you know what it all means?



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Lubrication Issues

- **Over-lubrication is the more typical problem**
  - **Often results in ground faults**
- **Shielded bearings commonly used**
  - **May or may not require lubrication**
  - **Follow manufacturer's instructions**
- **Always follow proper lubrication procedures**

Grease fitting

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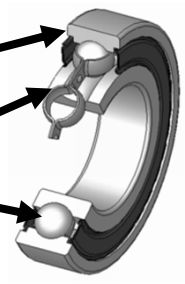
BEARINGS (Out of the box) ARE WEAK

- A bearing is a very weak thing until it is supported by the housing and filled by the shaft.
- The inner and outer races are subject to deflection and out-of-round conditions if they are not supported properly

Outer race is just a ring

Inner race is just a ring

Point contact from balls



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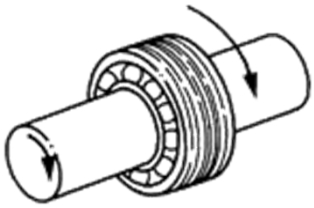
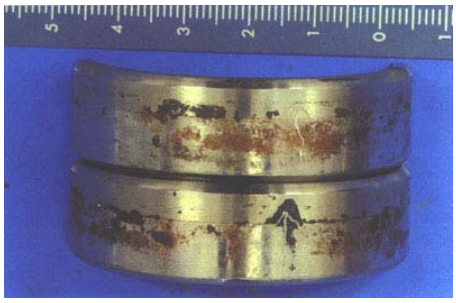
TROUBLESHOOTING
LOOSE FIT – Check Dimensions



BEARING CAN MOVE
SLIGHTLY IN HOUSING

FRETTING
CORROSION
"LOOKS RUSTY"
Atomic Bonding takes place



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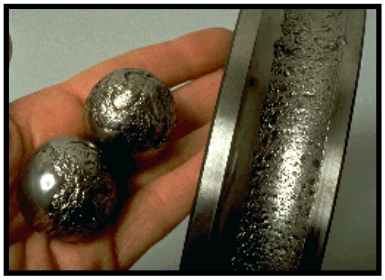
TROUBLESHOOTING EXCESS LOAD

- Same symptoms as normal fatigue although showing
  - heavier ball wear paths
  - greater evidence of overheating, and
  - widespread and deeper spalling (fatigue area)



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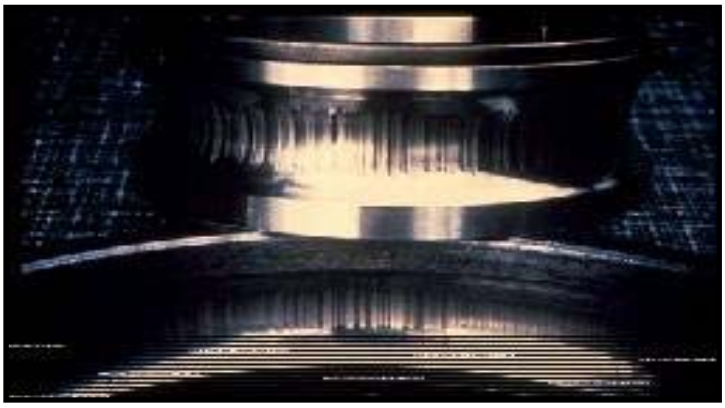
TROUBLESHOOTING ELECTRICAL FLUTING

Occurs when a current is passed through the bearing, instead of to a grounded source.



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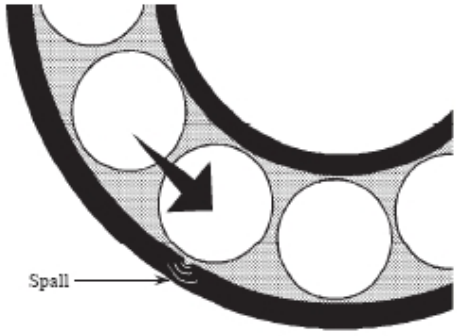
INTERNAL BEARING CONDITION

- A UNIQUE NOISE IS GENERATED WHEN a SPALL APPEARS IN a BEARING.
- THERE IS a RAPID RELEASE OF ENERGY, LIKE a SHOCK WAVE.



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TYPICAL BEARING CONDITION TABLE

BEARING READING	BEARING CONDITION
.00 to <.50 Bg'S	No cause for alarm. Bearing is good.
.50 to <1.00 Bg's	Most likely spalling has started. Be aware and alert. Attempt lubrication to double check.
1.00 to <1.50 Bg's	Minor to major bearing internal damage. Raceways and element debris will be found.
>1.50 Bg's	Seriously consider bearing replacement at the earliest possible time before catastrophic failure occurs.

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THERMAL INSTALLATION OF a BEARING

- Outside diameter of the bearing to be above 4” in diameter
- Bearing is not to be heated above 235^0 f –Delta coefficient
- Care must be taken to hold the bearing against the shaft shoulder while it cools to keep bearing from shrinking away from the shoulder

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BEARING INSTALLATION HAS TO HAVE PRECISE CONTROL

With Careful Measurement To Make Sure Dimensions Are Correct and Using Temperatures No Hotter Than 235^0 F

Make sure to demagnetize the bearing before removal

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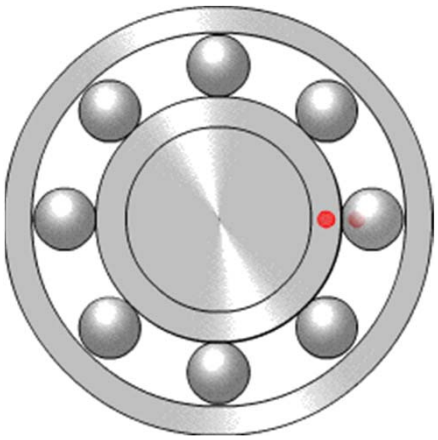
BEARING FAILURE ANALYSIS

TROUBLESHOOTING THE ROOT CAUSE OF BEARING PROBLEMS



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Troubleshooting Motors

- **Look for the obvious**
  - **Signs of physical damage, overheating**
  - **Coupling problems**
  - **Ambient temperature**
- **Mechanical Checks**
  - **Turns shaft by hand if possible**
  - **No vertical or horizontal movement**
- **Electrical Checks**
  - **Clamp-on Ammeter**
  - **Winding resistance**
  - **Insulation resistance**

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Contactors & Motor Starters Overview

- **Both use relay action principles to operate NO contacts for starting motors and other loads**
- **Definite Purpose Contactors**
  - **Sized by Full Load Amps (FLA) and Locked Rotor Amps (LRA)**
  - **For specific applications (examples):**
    - **Lighting**
    - **HVAC**
    - **Irrigation**
    - **Welding**
    - **Pools and Spas**

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Contactors & Motor Starters Overview

- **Motor Starters also have an Overload Device for protecting motors from extended overcurrent conditions**
- **Both NEMA and IEC rate Contactors and Starters**
  - ✓ **NEMA = National Electrical Manufacturers Assoc. rates equipment for U.S.**
  - ✓ **IEC = International Electrotechnical Commission rates equipment for countries worldwide including U.S.**
- **NEMA ratings based on maximum horsepower ratings**
- **IEC ratings based on maximum current**

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Contactors & Motor Starters Overview

- **IEC ratings based on maximum current and type duty**
  - **AC1 – non-inductive use**
  - **AC2 – slip-ring motors (i.e. low starting inrush)**
  - **AC3 – squirrel cage motors (most commonly used)**
  - **AC4 – inching and plugging**
- **"IP" rating refers to enclosure (similar to NEMA Type Enclosures)**

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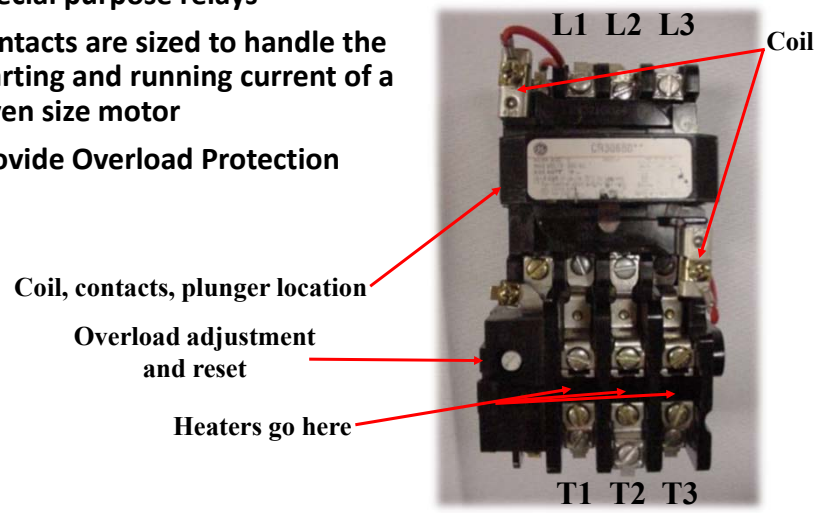
Magnetic Motor Starters

- **Special purpose relays**
- **Contacts are sized to handle the starting and running current of a given size motor**
- **Provide Overload Protection**



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Motor Overloads

- **Overload devices protect Motors against excessive heating due to overload condition.**
- **Different Types of Overloads:**
  1. **Solder Pots: Heater melts solder to operate trip mechanism**
  2. **Bimetallic: Heater bends bimetallic strip to trip mechanism**
  3. **Magnetic: Excessive current flow through coil eventually operates trip mechanism**
  4. **Solid State: current transformer senses current flow, measured electronically, operates trip mechanism**



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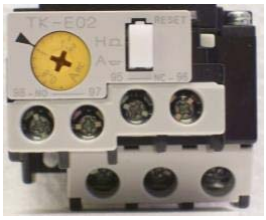
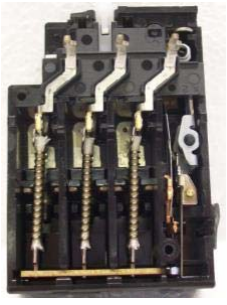
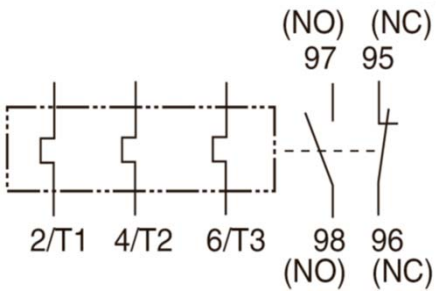
Your Bimetallic Overloads

- ✓ **Adjustable**
- ✓ **Can be set for Manual or Auto Reset**
- ✓ **3 heater elements**
- ✓ **Manual Trip/Reset**
- ✓ **N.O and N.C. contacts**



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Setting Overload Protection – general guidelines

- ✓**Motors with a marked service factor 1.15 or greater set at 125% FLA on nameplate**
- ✓**Motors with a marked temperature rise 40°C or less set at 125% FLA on nameplate**
- ✓**All other motors 115% of FLA on nameplate**
- ✓**Always check NEC Art. 430 for everything about a motor**

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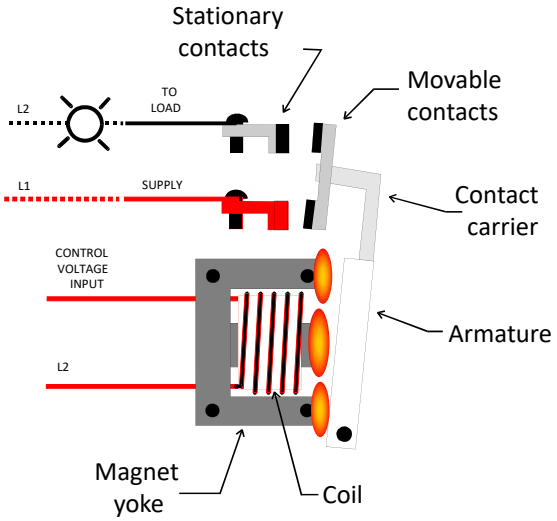
Relay Operation



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Understanding Motor Circuits

Remember: there are often Two separate circuits

1. **Main Power Circuit**
   - Applies main power to motor
   - Contains disconnecting means and OCPD's
2. **Control Circuit**
   - Opens and Closes Main Line Contacts to control motor
   - Works with sensing element in Main Power Circuit to provide "Overload Protection"
   - Becomes the "Ladder Diagram"

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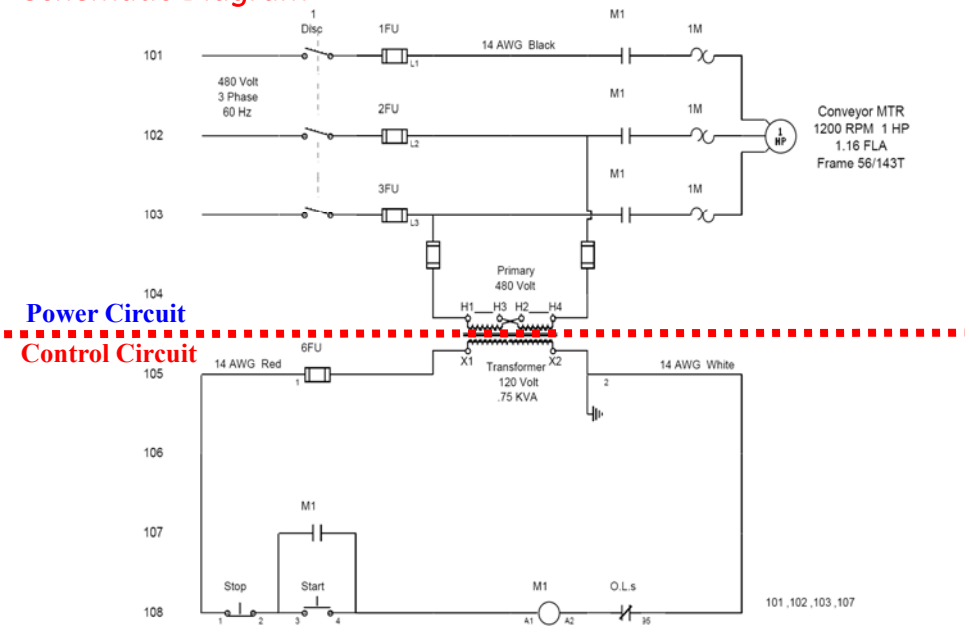
Schematic Diagram



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Troubleshooting Motor Circuits

Use a Logical, Systematic Approach

1. **Verify circuit operation is improper**
2. **Look for the obvious**
   - **Mechanical defects**
   - **Signs of overheating**
   - **Smell of burnt insulation**
3. **Check the Main Power Circuit, then the Control Circuit**

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Troubleshooting Motor Circuits

Check the Main Power Circuit

1. **Overloads reset?**
2. **Breakers not tripped?**
3. **Fuses checked?**
4. **Verify incoming power proper voltage.**
5. **Check voltage at top of motor starter and work upstream until the power loss is found**
6. **If all of the above okay, go to control circuit**

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Using Electrical Drawings, to troubleshoot you must know the different types of drawings:

Single-line diagrams
- distribution flow

Wiring diagrams
- location of terminations

Schematic diagrams
- electrical operation

Ladder diagrams
- control circuit

Floor Plans
- branch circuits & wiring

Site plans
- is your facility a campus-style?

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Typical uses for the One-Line (Single-line) Diagram

- **Trace power through facility**
- **Determine Device Ratings**
  - **Are the OCPD's sizes installed per the drawing?**
  - **Has new equipment been added?**
- **If new equipment has been added**
  - **Are the drawings updated?**
  - **Are conductor sizes adequate now?**
  - **Is proper selective coordination retained?**
- **Resetting "86" devices**

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Device Function Numbers
(commonly used)

- **20 Electrically Operated Valve**
- **21 Distance Relay**
- **23 Temperature Control Device**
- **25 Synchronizing Device**
- **26 Apparatus Thermal Device**
- **27 Undervoltage Relay**
- **28 Flame Detector**
- **30 Annunciator Relay**
- **50 Instantaneous Overcurrent**
- **51 AC Time Overcurrent**
- **52 AC Circuit Breaker**
- **55 Power Factor Relay**
- **57 Short Circuiting or Grounding Device**
- **59 Overvoltage Relay**
- **60 Voltage or Current Balance Relay**
- **61 Time Delay**
- **63 Pressure Switch**
- **67 AC Directional Overcurrent**
- **71 Level Switch**
- **72 DC Circuit Breaker**
- **74 Alarm Relay**
- **86 Locking-out Relay**
- **87 Differential Protective Relay**

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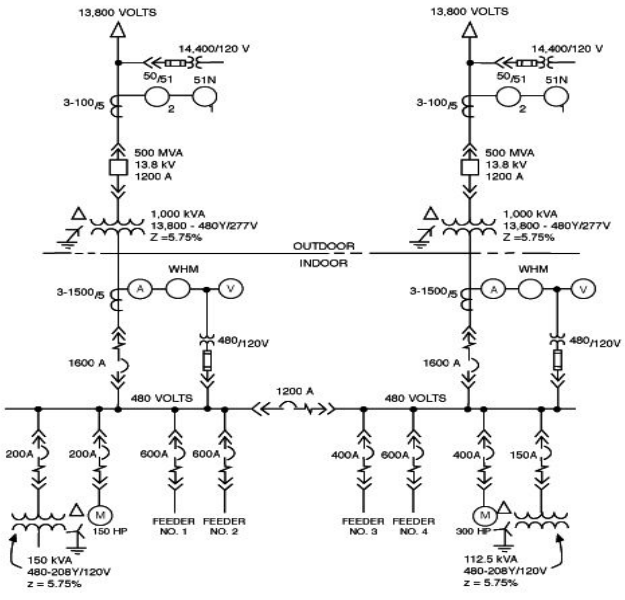

TYPICAL ONE-LINE DIAGRAM

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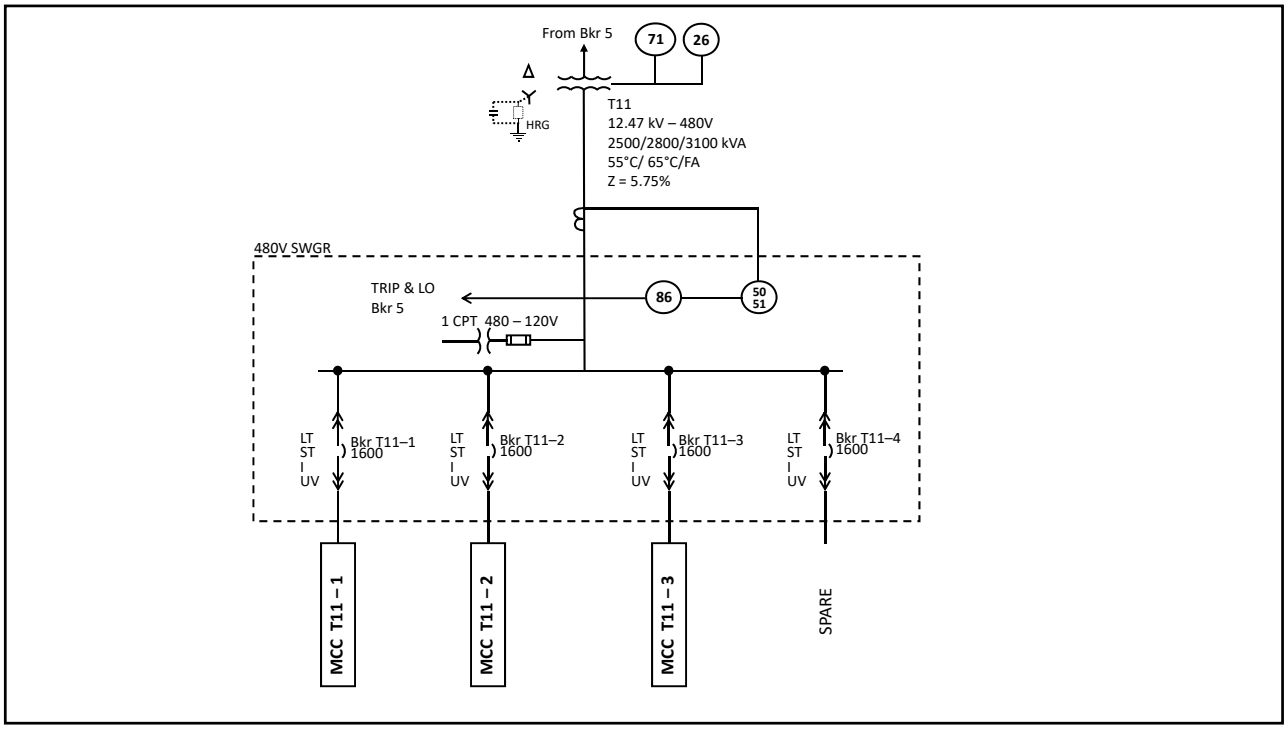

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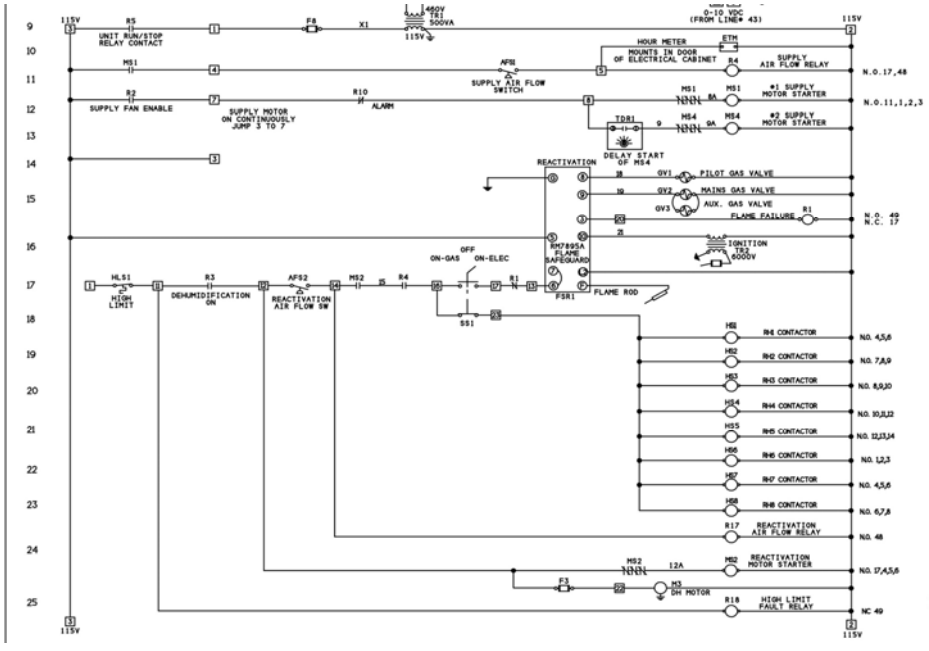
Example Ladder Diagram



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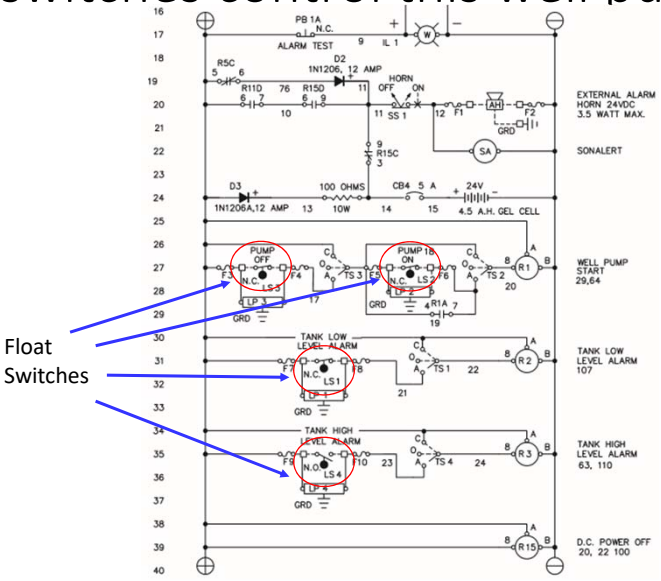
What switches control this well pump?



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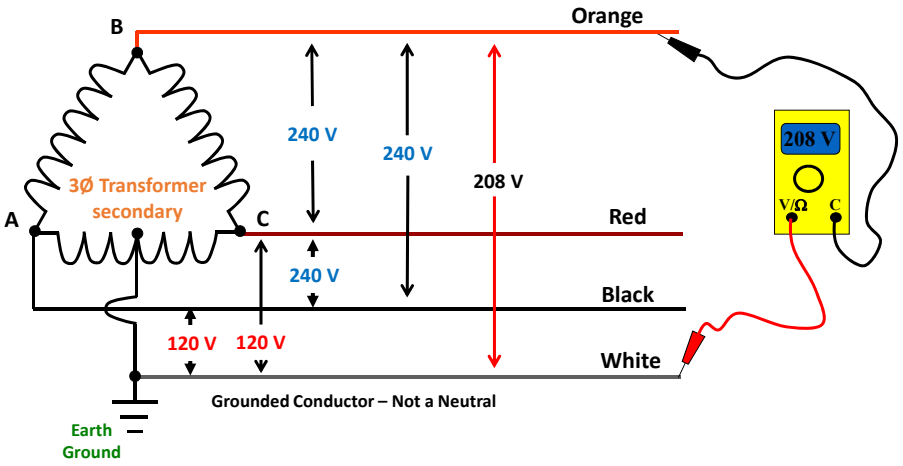
120/240 VAC, 3Ø, 4-wire System (Delta High Leg)



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Phase Unbalance

- Too many single-phase loads on one particular phase results in lower voltage on that phase compared to other two
- One winding in motor will then be at a lower voltage than other two
- Unequal voltages resulting in circulating currents in motor – overheating and failure

Maximum recommended phase unbalance:

Voltage Unbalance	< 1%
Voltage %THD	< 5%
Current Unbalance	< 10%

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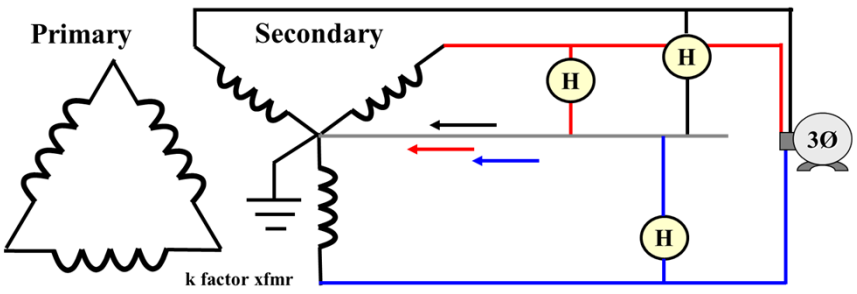
3Ø Distribution – Why the Neutral Overheats



H = Nonlinear Load (generates harmonic current)

Harmonic currents
- Are in addition to normal current flow in the system
- Additive, thus overheat neutral
- Also flatten out top and bottom of 60 Hz sinewaves
- Typically a combination of solutions to overcome

1Ø loads must be balanced across the 3 phases.

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Let’s look at our hand outs and review the test--

Questions????

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