

AN OVERVIEW OF MOTOR CONTROLS TROUBLESHOOTING & MAINTENANCE**¹A. I Akwu, ²A. K EKpa, ³D. U William & ⁴P. A Enyiong.****¹Electrical Electronics Engineering Department, Federal Polytechnic, Nekede, Owerri. Imo State, ²Electrical Electronics Engineering Department, Akwa Ibom State Polytechnic, Ikot Osurua, Ikot Ekpene, ³Works Department, Akwa Ibom Local Local Government Service Commision, Urueoffong Oruko LGA., ⁴Exxon Mobil Training Center, Eket, Akwa Ibom State, Nigeria***Email: afikana@outlook.com***ABSTRACT**

The need to improve industrial control systems is a dynamic and ever-changing process. Automated devices are being developed at rapid rates. The control systems today, offer reduced personnel and production costs and increased safety, manufacturing efficiency, and quality control. Industrial power controls are used to regulate such devices as electric motors, heaters, conveyors, machine tools, pumps, production operations etc. Motor controls for example provides a wide variety of functions for the motor, such as starting and stopping, reversing, accelerating, decelerating, braking, and performing time-controlled operations. The motor control is as important to the motor as the power that drives it. The purpose of this paper is to examine troubleshooting and preventive maintenance of industrial motors controls. The basic theory of industrial power controls is presented, along with types of controllers, testing procedures, and preventive maintenance.

Keywords: Control System, Motor Controls, Troubleshooting, Maintenance, Controllers

INTRODUCTION

Motor Controllers and Drives are electrical or electronic devices that regulate motor speed, torque, and position outputs. The drive modifies the power input to the motor to achieve the desired output. The controller circuits are commonly integrated with the drive circuits as one stand-alone unit, thus the terms motor drive and motor controller are frequently used interchangeably. There are four basic motor controller and drive types: AC, DC, servo, and stepper, each having an input power type modified to the desired output function to match with an application. AC motors drives are used to control the speeds of motors that drive pumps, fans, etc. where traditional valves or dampers might otherwise be used to throttle the flow. AC motor drives are used to increase efficiency by setting pump, fan, etc. speed to exactly match requirements. DC motor drives are used to control permanent magnet DC motors running from AC sources. DC motors have very good low-speed torque, making them especially suited to winches, cranes, etc. where loads have to be lifted without a "running start." Before the advent of electronic DC controls, DC motors were often coupled as motor-generator sets to produce direct current via AC induction motors. Servomotor controllers and drives rely on feedback from the servomotors to control position, velocity, acceleration, etc. <https://www.thomasnet.com/articles/instruments-controls/types-of-motor-controllers-and-drives/>. When repairing motor control circuits, troubleshooting using methods such as multimeter usage, schematic reading, or component testing can be important. Listen for unusual noises, smell of burning, or sensing heat. It would be hazardous, and could result in increased costs, to approach a problem without consideration of the range of potential causes and solutions. The system components evaluation, diagram analysis, and equipment inspection is very important. There must be safety checklists, operating procedures, and troubleshooting guidelines in place. Work that is completed should be tested and verified on a regular basis to ensure safe, repeated operations. <https://lpmanagementservices.com/the-importance-of-troubleshooting-for-safe-motor-control-operations/>. Proper inspection, training and

troubleshooting improves safety for long-term sustainability of equipment and operations, and most importantly, for the health and well-being of employees, partners, vendors and customers. The paper layout is as follows; Section 2 explains the basis of motor controls circuits and panels, section 3 the Importance of troubleshooting for safe motor control operations. Section 4 explains the control circuits troubleshooting systematic methodology in section while section 6 explains motor control troubleshooting and maintenance. The paper is concluded in section.

Motor Control Circuits and Panels

Motor control circuits are an effective way to reduce cost by using smaller wire and reduced-amperage devices to control a motor. Imagine trying to wire a pushbutton station for a 100A motor using 3 AWG conductors. Many smaller motors use the same size conductors for both control and power circuits, but as the horsepower increases it becomes impractical to do so. Motor control circuits are often connected to lower voltages than the motor they control to make it safer for operators and maintenance personnel. A motor control circuit, for the most part, is simply a switch (or group of switches) and a motor. Many control circuits include motor overload protection devices. Traditional overload (OL) protectors operate on the relationship between heat and current. As current increases, heat increases. If an overload device is rated 10A, and the current exceeds that rating, the OL device will operate to open the circuit because of the increased heat caused by the current running through it. A magnetic starter or other motor controllers may include overload devices, or they may be an integral part of the motor, particularly with small motors. Electrical symbols, words, and line diagrams provide the information necessary to understand the operation of motor control circuits. Used together, they create a type of motor control “language” that is used to transfer information and ideas quickly and efficiently. The symbols in motor control schematics represent devices, power conductors, control conductors, conductor connections and terminals, and sometimes the motor itself. The basic types of schematics are shown in Figure 3.

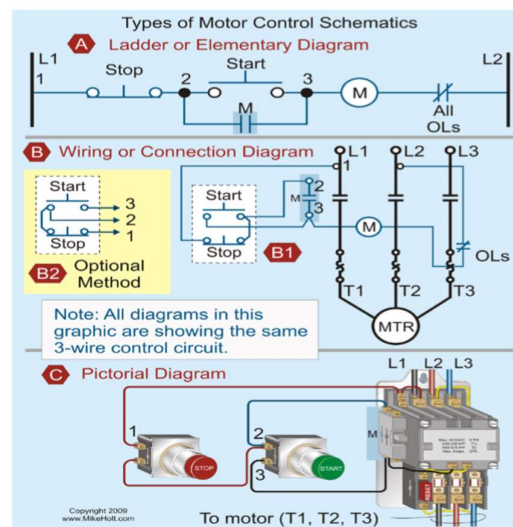


Figure 3. Types of Motor Control Schematics

Parts A, B, and C of that figure illustrate three different methods of representing the same control circuit. <https://precisionautomation.net/2019/04/01/basic-principles-of-motor-controls/>

Ladder diagrams are also called “line diagrams” or “elementary diagrams.” They’re used to represent the function of the control circuit and the associated devices, but don’t show the components of the control circuit in their actual positions. As control circuits become more complex, a ladder diagram can be less complicated to read than a wiring or connection diagram.

Connection diagrams, or wiring diagrams, show the components of the control circuit in a semblance of their actual physical locations. The start-stop push-button station is shown more as an actual device in the control circuit wired to a set of contacts marked 2 and 3.

Pictorial diagrams are often used in educational material and as exploded views or cut-away views in installation and maintenance literature. Pictorial diagrams help students see actual devices and components used in motor control circuits and how they relate to the symbols used in ladder diagrams and wiring diagrams. Different manufacturers of control devices use different methods of showing the control circuit wiring. For example, in Figure 3B1, the control wiring from the start-stop pushbutton station runs to the actual connection points 1, 2, and 3. As the wiring diagrams become more complicated, the optional method shown in Figure 3B2 is frequently used to show the connection points for the start-stop pushbutton station.

Motor control panels come in a variety of shapes and sizes, but all serve the same purpose: to provide power and control for electric motors. The most common type of motor control panel is the starter panel, which houses the starter and associated controls for an electric motor. Other types of motor control panels include distribution panels, which distribute power to multiple motors; motor control centers, which provide centralized power and control for multiple motors; and combination starter panels, which combine the functions of a starter panel and a distribution panel. While motor control panels can be used for a variety of applications, they are most commonly found in industrial and commercial settings. <https://www.industlabs.com/news/what-are-the-different-types-of-motor-control-panels>. Some examples of different types of motor control panels include but are not limited to;

- **Starter panel:** A starter panel is the most basic type of motor control panel. It houses the starter and associated controls for an electric motor. The starter panel may also include a circuit breaker to protect the motor from overload.
- **Motor control center:** A motor control center provides centralized power and control for multiple motors. It typically includes a starter panel, distribution panel, and motor control unit.
- **Custom Across-The-Line Combination Starters:** An Across-The-Line Combination Starter is an electrical device that is used to start a three phase induction motor. It consists of three contactors, a thermal overload relay, and a push button control station. The contactors are used to connect the motor to the power supply, the thermal overload relay is used to protect the motor from overheating, and the push button control station is used to manually start and stop the motor.

Importance of Troubleshooting for Safe Motor Control Operations

Motor failure can cause severe problems; having a comprehensive plan for approaching the problem in a safe manner is imperative. The Occupational Safety and Health Administration (OSHA) requires under its safety required work practices that employers shall ensure electrical equipment is free from recognized hazards that are likely to cause death or serious physical harm to employees. Given that it is not probable for any one solution to apply to all motor control systems within industrial operations, a comprehensive approach to problem solving must be adhered to. Systems, situations, and facilities are not identical therefore having as much background information as possible combined with proper safety training in how to inspect, safely troubleshoot, and diagnose a problem is crucial when operating motors within manufacturing and critical/mixed use facilities. A trained technician in safety operations understands the importance of proper inspection, lockout/tag out procedures, and troubleshooting. <https://lpmanagementservices.com/the-importance-of-troubleshooting-for-safe-motor-control-operations/>. It is imperative that site-specific procedures include verification that energy sources are in a zero energy state. In the case of electrical energy, verification has to comply with requirements of NFPA 70 E Standard for Electrical Safety in the Work Place. Knowing how to carefully perform tests, having acute observation of sight and smell, and asking the right questions

will help ensure safety of employees. Thorough troubleshooting can help uncover and identify faults, determine a need for repairs or replacement parts, cut costs, reduce down time, and ultimately promote safety.

Control Circuits Troubleshooting Systematic Methodology

This is the key to quickly and effectively troubleshooting control circuits. Even the most experienced troubleshooter must rely on a systematic troubleshooting process to solve control circuit problems. At a high level, a good troubleshooting process is simple and involves the following steps;

1. **Investigate the symptoms:** Make sure you understand the system. Pull any available documentation, whether online or hardcopy. Look for schematics and piping and instrumentation diagrams, as well as loop sheets. Talk to the operators and anyone else familiar with the operation. Look up operations and maintenance records and control and configuration parameters.
2. **Identify the possible causes:** Analyze the system with an open mind, systematically eliminating components and functional elements from the overall process as unlikely trouble spots. Start by following the logic through from input to output i.e. what happens in the cause-and-effect chain. Compare the current symptoms with the action that the specified control algorithm should produce. As you eliminate some possible causes, you can also start building and prioritizing your list of most likely causes, making room for testing the system to eliminate these possibilities.
3. **Test the system and verify possible causes:** After narrowing the probable cause list down to a manageable size, commence testing. Once the process is back up and running, first do those tests that don't interrupt operations. Quick and easy tests can save you time in eliminating potential causes, so do those early in your troubleshooting. In many cases you need to look, listen, or feel specific components. When working around or with energized equipment, don't take chances with safety. In all cases, follow established and required safety procedures.
4. **Follow through:** Follow through with careful replacement of faulty parts, a period of monitoring the operation, and documentation of what you did according to the system requirements. If your action was a quick fix to get equipment up and running, follow your system's root-cause analysis procedure to get to the bottom of the problem.
<https://www.ecmweb.com/content/article/20893317/troubleshooting-control-circuits>

One of the main jobs of an industrial electrician is to troubleshoot and repair a control circuit when it fails. In order to repair or replace a fault component it is necessary to determine which component is at fault. The three main instruments used by an electrician to troubleshoot a circuit are the voltmeter, ohmmeter, and ammeter.

Checking Circuit with Power: It is often necessary to troubleshoot a circuit with power applied to the circuit. When this is the case, safety should be the first consideration. When de-energizing or energizing a control cabinet or motor control center module, the electrician should be dressed in flame-retardant clothing while wearing safety glasses, a face shield, and a hard hat. Motor control centers employed throughout the industry generally have the ability to release enough energy in an arc-fault situation to kill a person 30 feet away. Another rule that should always be observed when energizing or de-energizing a circuit is to stand to the side of the control cabinet or module. Do not stand in front of the cabinet door when opening or closing the circuit. A direct short condition can cause the cabinet door to be blown off. After the cabinet or module door has been opened, the power should be checked with a voltmeter to make certain the power is off. A procedure called check, test, check should be used to make certain that the power is off.

1. Check the voltmeter on a known source of voltage to make certain the meter is operating properly.

2. Test the circuit voltage to make certain that it's off.
3. Check the voltmeter on a known source of voltage again to make certain that the meter is still working properly. https://www.industrial-electronics.com/Motor_Control_12-60.html

Understanding the Ladder Diagram: One of the first steps to successful troubleshooting is to understand the concept of the ladder diagram. Control circuits may be arranged much like a ladder (i.e., with rails vertically on each side and rungs horizontally between the rails). Just as you step your way down a ladder from the top, troubleshooting requires you step your way down a ladder diagram, one rung at a time, while analyzing each rung from left-to-right. <https://www.ecmweb.com/maintenance-repair-operations/motors/article/20900101/troubleshooting-motor-control-circuits-part-2>

The circuit in the Figure 5.0 is a facility process control system that allows an operator to recharge a tank if tank pressure drops below a certain point.

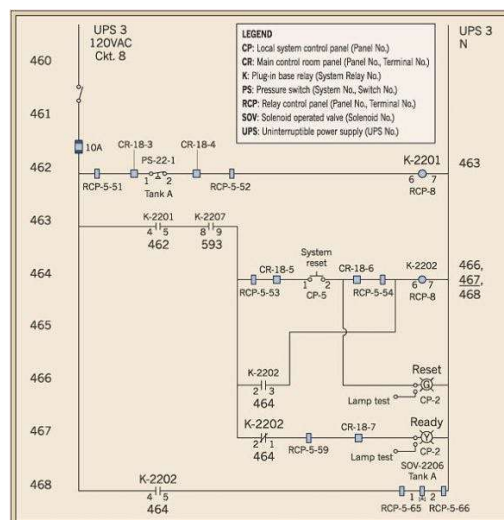


Figure 5.0 Control system diagram for managing the tank pressure in a processing plant.




To re-pressurize the tank, certain conditions (i.e., permissive) must be met, and the tank must stop pressurizing automatically at a given set point. Let's walk through the circuit operation to show you how it works.



1. Upon low pressure in the system, PS-22-1 contacts are closed, and the K-2201 relay is energized, thus closing contacts on rung 463.
2. Rung 463 contact K-2207 is closed when the K-2207 coil is energized. (Coil is on a later rung and not shown). Certain conditions must be met to operate these contacts, and line 593 would have to be analyzed to determine specifics.
3. On Rung 463 with both the K-2201 and K-2207 contacts closed, the YELLOW READY lamp comes on, indicating the system is ready to be re-pressurized.
4. On Rung 464 depressing SYSTEM RESET energizes K-2202. GREEN RESET lamp will be ON as soon as the RESET button is pushed.
5. Rung 466 contact closes and is a holding contact for SYSTEM RESET.
6. Rung 467 K-2202 contacts open to turn off the YELLOW lamp.
7. The contact on line 468 closes to energize the solenoid-operated valve SOV-2206, which begins re-pressurizing Tank A.
8. When the tank pressure returns to normal, PS-22-1 opens at its high-pressure set point to de-energize all relays and lamps, and de-energize SOV-2206 to stop pressurizing the tank.

Motor Control Troubleshooting and Maintenance

A motor may not start for a variety of reasons. Knowing what to check for and where to begin is a valuable skill that can reduce downtime when a fault occurs. Usually, there are two fundamental steps in troubleshooting. The first is a cursory visual inspection, followed by a more in-depth examination with testing equipment and referencing several diagrams. Motor control circuits have several protective devices built into them to protect wires and equipment. It is always a good idea to start your visual inspection by checking overload and overcurrent devices. A visual inspection sometimes quickly locates a fault or identifies situations requiring maintenance. For example, you might see a tripped indicator on a circuit breaker, switch or overload relay. Resetting the device might be all the circuit needs to resume working. If an overload or overcurrent situation has occurred, it is advisable to find the source of this fault. A visual inspection can identify burnt or heat-discolored components, loose wires in terminal blocks, or mechanical parts that bind together or cause excessive friction. When there is no obvious cause for the problem(s), it is often necessary to analyze circuit diagrams and take measurements of voltage and resistance at key points of the circuit. To do this, we use voltmeters and ohmmeters. A firm understanding of their use and limitations is necessary for their safe operation in circuits. <https://opentextbc.ca/basicmotorcontrol/chapter/common-issues/>. Apart from the information above, the respective parts of the MCC is not left out in the troubleshooting process. The table below tabulates the basic component troubleshooting. <https://automationforum.co/basic-troubleshooting-of-electrical-components-in-mcc-electrical-control-panel-switch-gear/>

Table 1.0 Basic MCC troubleshooting

Basic troubleshooting of Electrical components in MCC/Electrical Control Panel/Switch Gear					
sn	MCC Component	Possible fault	Identification	Cause	Remedy
1	Switch Disconnect Fuse 	Fuse Burning	Check the fuses continuity with a Multi Meter.	Over Current, Short Circuit	Replace the Fuse with same rated(Current and Voltage) new one
2	Miniature Circuit Breaker 	Tripping	Short Circuited current.	Rectify the cause produced the tripping current and once rectified the same. Put ON the MCCB/MCB	Voltage, Current, Withstanding Fault Current
3	CONTACTOR 	Motor not starting.	Contactor Coil faulty, Coil is not getting Power	Check the Power Supply voltage from Coil point. If coil is faulty replace with new one.	Voltage, Current, Maximum fault withstand Current.

4	Overload Relay 	Motor not starting/Motor tripping continuously	Relay Tripped, Current adjustment is faulty.	Release the tripped OLR switch, Adjust the current rating according to the Name Plate.	Current and Voltage.
5	RELAY 	Not Working.	Coil faulty, No power, Contact got damaged	Check the power Supply voltage, Continuity between contacts, wiring faulty.	Coil Voltage, Current Ratings, Type of Contact.

To carry out maintenance in a motor control circuit, the controller has to be de-energized. The inspection of de-energized equipment is very detailed and has several steps. In the following sections, we will delve further into each of the preventative maintenance methods and the technicalities of each. <https://www.baypower.com/blog/motor-control-center-preventive-maintenance-checklist/>. The processes of inspecting de-energized equipment is technical and requires more training than basic visual inspections. Therefore, when performing routine maintenance, it is essential to refer to the manufacturer's manual, and adhere to relevant standards. In addition, the manufacturer's user or installation manual should outline maintenance steps. Several primary components on de-energized equipment must be inspected. These components include examining the structure, buses and splice connections, protection devices for the wiring and branch circuits, handle mechanisms, starters, and contactors. The structure needs to be examined for moisture or other signs of dampness within the motor control center. Any moisture or condensation originating from an outside source can lead to the failure of the system. If there is moisture in the system, ensure that the moisture is eliminated and seal off the space or conduit that allows the water to enter before re-energizing the equipment. Any damp insulation material will need to be replaced, dried, or cleaned. Motor control circuits needs preventative maintenance to extend their lifetime usefulness and prevent electrical hazards and equipment failure. There are guidelines and standards that electrical systems such as motor control circuits need to meet. When the manufacturer's manual is unavailable, professional standard guidelines can substitute for their absence and help to determine the necessary and proper maintenance. Below is a detailed checklist on what should be done to help prolong and extend the life expectancy of your MCC. For visual and mechanical inspection, complete the following list:

- Use drawings and specifications to compare the equipment nameplate data.
- Examine the physical and mechanical condition of the motor control
- Examine anchorage, alignment, and grounding. Ensure the MCC meets requirements.
- Ensure the unit is clean - check for dust buildup or residual moisture, or condensation.
- Examine bolted electrical connections for high resistance by utilizing at least one or more of the following methods:
- Test all electrical and mechanical interlock systems to ensure proper sequencing and operation.

- Confirm the correct barrier and shutter installation and operation.
- Utilize and examine all active components and confirm the correct operation of all signifying devices.
- Examine and evaluate the contactors.

Preventative care and maintenance are vital in keeping low-voltage motor control circuits functioning correctly. While the motor control circuits components will likely need replacement over time, upkeep on motor control circuit equipment will help avoid replacing the entire system until necessary. Inspecting de-energized motor control circuit takes quite a few steps but effectively locates flaws and potential hazards.

CONCLUSION

This paper explained the basic concepts and the different components of the motor control circuits. It provided an overview of motor control circuits troubleshooting systematic methodology and goes on to explain the troubleshooting and preventive maintenance of motor control circuits because failure to do routine preventative maintenance on motor control circuits could lead to costly fixes, loss of revenue due to shut down, and safety hazards

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