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# Troubleshooting on the Main and Control Circuit of Three Phase Induction Motor

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**Abstract**

Technical personnel working in a factory or industry usually carry out repairs and maintenance of industrial motors and generators. This paper presents simplified and quick method of troubleshooting the main and control circuits of three phase induction motors in order to avoid delay during production period. This is achieved by examining the power quality, circuit components (interpretation of circuit diagram), insulation condition, rotor core and air gap by specific testing equipment for each fault zone for fault detection.
**Keywords:** Troubleshooting, Main and Control Circuits, Power quality, Circuit components, Rotor core, Insulation condition, Air gap

## 1. Introduction

Troubleshooting is how to find the cause of unhealthy or faulty zone in main or control circuits of rotating machines in order to repair and put the motor into good working condition [1]. Before troubleshooting on faulty circuits, you must test and ensure that the following parts and parameters are normal and satisfactory. The rotating shaft rotates freely and the bearings are in good condition. The supply voltage and the frequency must correspond to the ratings on the nameplate. The voltage must be available on the machine terminals. Protective devices, connections, contacts are properly made in the circuits between the control apparatus and the machine. In [2], the machine should be switched off and the power source is isolated before working on it. To start troubleshooting on the main and control circuits of any rotating machine, one must first be familiar with organization or industrial safety rules and procedures. These rules and procedures such as logout, tagout and testing procedures will help you while troubleshooting. You must understand the machine operational design manuals and drawings and the machine history record to see if there is any recurring problems [3]. The technical personnel troubleshooting must be mentally and physically fit so that he can reason and observe carefully any loose connections or components, overheating of coils, smelling of burnt components and of course the unusual sound of the faulty machine. If brushes display intensive sparking, this may be due to the contact surface of the bus ring that is damaged or the brushes got worn out. Your observation and reasoning can then be used to define the problem area of the malfunctioning machine. Repairing the faulty circuit should not be commenced immediately unless the cause of the malfunction or problem is identified [4]. Appropriate testing equipment should be available for qualified persons for adequate diagnostic procedure of the components of the circuits. Electrical maintenance personnel have been limited to troubleshooting with only a multimeter and a megohmeter. There are no accurate tests with necessary measuring devices for fault detection and confirmation. Unfortunately, these do not provide enough information to allow most technicians and engineers to feel totally confident in determining if an electrical problem exists or not. In this paper; power quality, power circuit components, insulation condition, stator and rotor conditions and air-gap are considered and discussed as possible faulty zones. Early detection of faults and putting the machines in order increase production rate. There are different types of main and control circuits such as jogging, plugging, forward-reverse, starter (direct on line, star-delta, autotransformer, rotor resistance) but the starting of an induction motor by star-delta circuit is taken as a key study. Fault can be minimized through scheduled routine inspection and maintenance [5].

### 1.1 Power quality

The alternating voltage supplied by a utility is sinusoidal which is having magnitude and frequency by national standards specifications having zero impedance at all frequencies. There is no real-life power source that is ideal, and the problems associated with power quality are the variations in root mean square or peak voltage, variations in frequency and variations in voltage and current waveforms known as harmonics. The incoming voltage supply to the main and control circuit must be thoroughly checked to ensure that it is free from harmonic content. The operation of induction motor operating above normal rating causes saturation of its magnetic circuit and large magnetizing current resulting into heating and low power factor. A supply voltage too low reduces the starting torque of the motor. Power monitoring, power quality and power quality recorder devices can be used for monitoring currents, voltages and harmonics in order to support power systems availability and reliability. Poor power quality can be detected and measured by oscilloscope and anything different from sine wave could be an indication of trouble. In the absent of power quality harmonic testing meters, troubleshooting is incomplete. If a healthy machine is installed in an unhealthy or faulty power circuit, voltage and current imbalances results, and temperature increases which will lead to the breakdown of that machine. NEMA recommends that if the voltage imbalance in any rotating machine reaches 5% the motor should not be operated. Figure 1 below shows the presence of harmonic distortions from the incoming supply voltage.

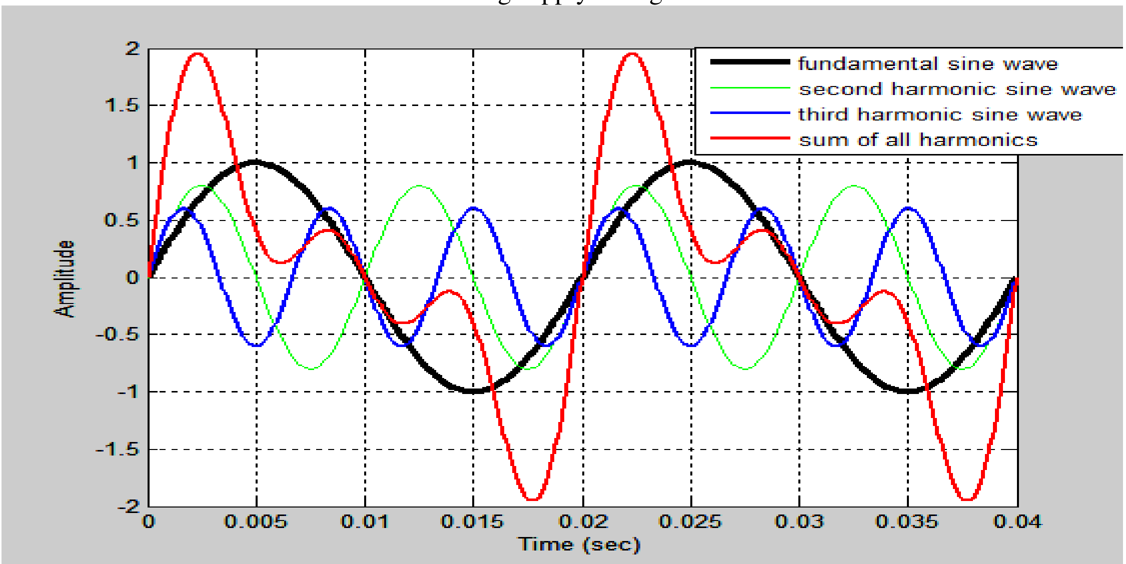


Fig. 1: Fundamental, second, third harmonic voltage sine wave and the resultant

The nature of the free harmonic content of voltage sine wave is represented by thick black line while the second, the third and the sum of all the harmonics (resultant) is represented by green, blue and red lines respectively.

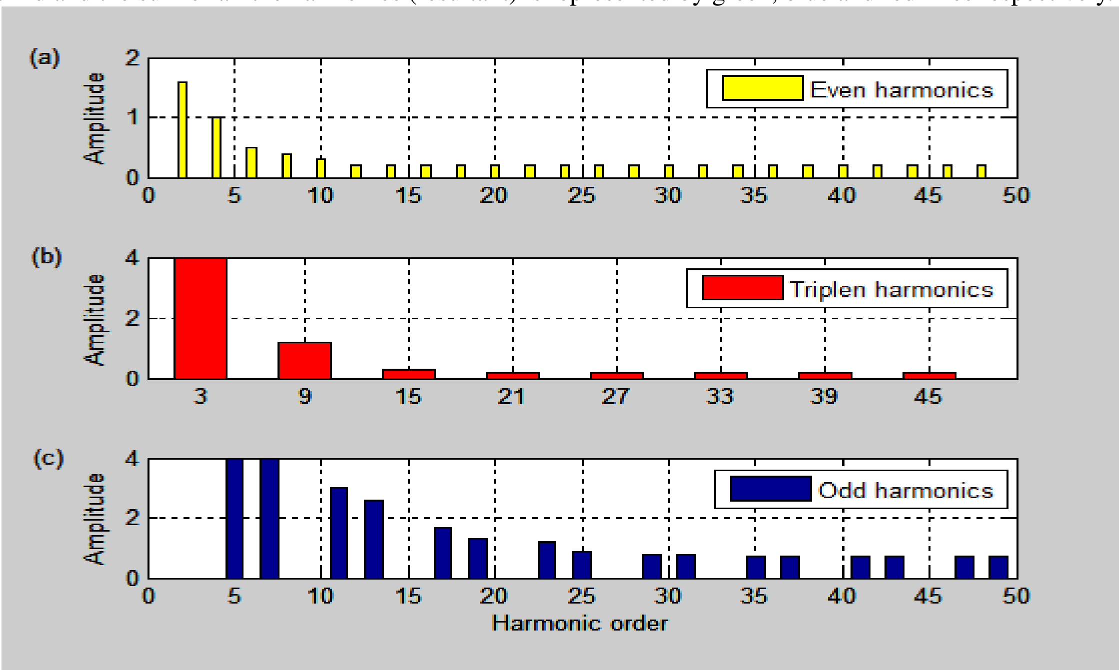


Fig. 2: Maximum permissible harmonic levels in percentage for 230/240V

Figure 2 shows the standard maximum permissible harmonic levels in percentage for 230/240V and regardless of the current drawn by the load**,** and nothing should be allowed to be connected to the supply that may cause voltages exceeding the above limits to appear on the supply. Figure 2(a), 2(b) and 2(c) show even, triplen and odd harmonic content that may be present in supply system.

 

### 1.1.1 Circuit components

The main and control circuit consist of stator winding (star or delta), supply main cables, circuit breakers, main contactors, overloads, earthed wires, fuses, the terminal box, thermistor contactor and the prescribed control wire sizes. All these components should be reliable and applicable where necessary in the circuit. The high resistance connections are caused by loose cables, open fuse clips, corroded fuse clips, open leads and corroded terminals and these reduce the horsepower rating. NEMA provide derating curve that shows a factor for derating motor horsepower as a result of voltage imbalance. Contactors like normally open (NO) contactor relay, normally close (NC) contactor relay and timer relays such as normally open time closing (NOTC) and normally close time opening (NCTO) and auxiliary contactors should be properly checked. Ensure that 1.5 $mm^2$ cable is protected by 15A fuse and 2.5 – 4.0$mm^2$ is also protected by 20A fuses and that the prescribed control panel cables such as (2X0.5……2.5$mm^2$/1X4$mm^{2,}$ 2XAWG14/1XAWG12, 2X0.5 – 1.5$mm^2$/1XAWG14) are used.

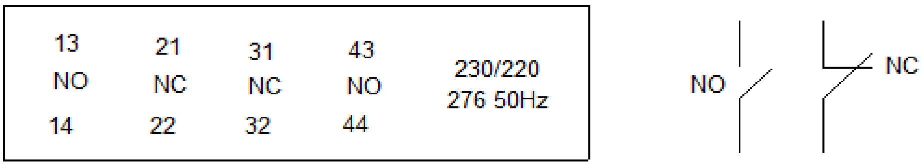


Fig. 3: contactor relay

The contactor relay in Figure 3 is mainly connected to the main circuits of a three phase machine and this conects the machine especially the three phase inductons motor to the supply

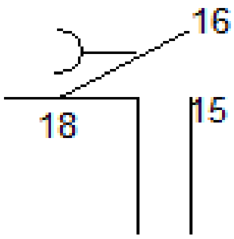


Fig. 4: Off delay relay type 7PU4620

The off delay relay in Figure 4 is used as a timer relay. When the coil of the relay is energised, it is delayed for some few seconds before its normally open contact closes. This type of relay can be used in the star-delta starting of three phase induction motor

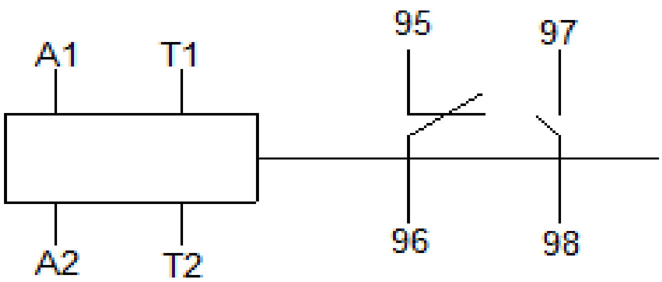


Fig. 5: Thermistor

contactor – 3UN21

A thermistor in Figure 5 is a transducer that acts as a thermally sensitive resistor. Its resistance changes with a change in temperature. An increase in temperature causes a decrease in its resistance and the current flowing through it increases. This thermistor is used for protecting sub distribution boards in staff quarters and connected to sounding device should in case of rise in temperature in order to prevent fire outbreak.

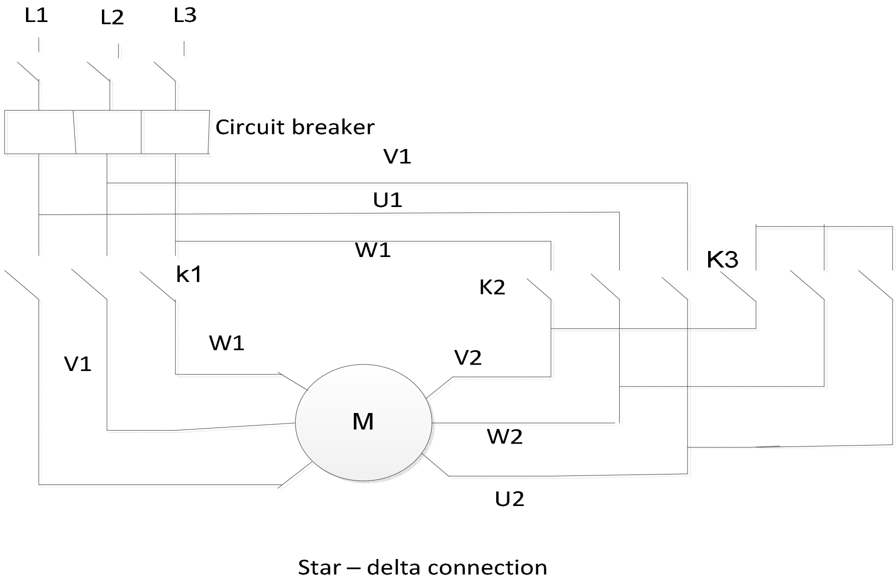


Fig. 6: Main circuit of electric motor connected in star-delta

The main circuit of an induction motor connected in star-delta in Figure 6. The circuit breaker breaks the circuit if there is overload or short circuit or any factor that causes a rise in the temperature of any of the phase winding in the motor. The main magnetic contactors are contactor K1 which connects the motor to the power supply, contactor K2 connects the motor in delta connection and contactor K3 connects the motor in a star connection.

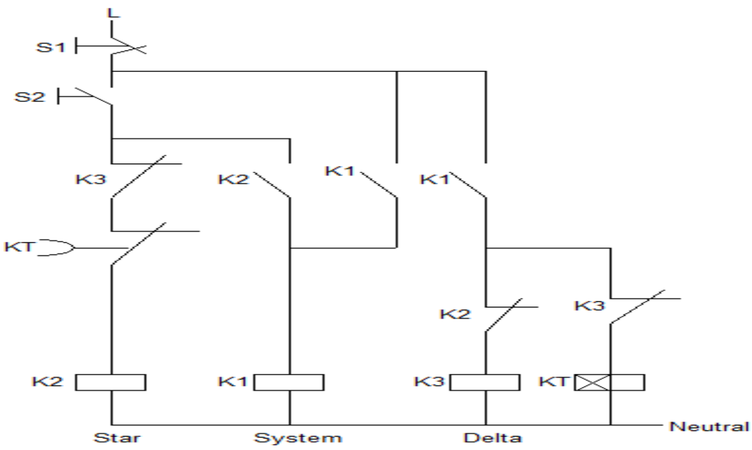


Fig. 7: Control circuit for star-delta connection

The control circuit of the main circuit is shown in Figure 7. Its principle of operation is explained as follows: When the circuit start button S1 is put on by pressing downward the push button, momentary coil K2 is energized and the normally open auxiliary contact K2 normally open before the energizing of its main coil closes while the normally close contacts K2 opens. As the auxiliary contact K2 that connects the main system magnetic contactor coil K1 closes, the system contactor coil K1 energizes immediately and the motor begins to run in star connection. In star connection, only the phase voltage is applied and the motor will develops only 33% torque and will draw only 33% of the normal starting current. After a predetermined time, the off delay timer relay coil KT de-energizes and its normally close contactor KT disconnects the star contactor coil K2. The starter changes the motor coil to delta which is the full voltage running connection. The system contactor coil K1 remain energized throughout the running period of the motor with the help of the auxiliary contact K1 that is closed permanently during the running period except the stop off button S1 is pressed down to off the circuit.

### 1.1.2 Insulation condition

Insulation should be between turns of winding, coils and solder joints. An insulation breakdown can result in an expose of leakage current and the personnel will be unsafe such situation. The electric current should be made to

 

flow through the conducting path and avoid the current coming in contact with personnel [6]. Voltage transients such as surges and spikes caused by variable frequency drives lower the dielectric strength of the conductor insulators. IEEE recommends the insulation resistance can be tested by the prescribed minimum acceptable reading of 1 megohm plus 1 megohm per KV of the motor rated voltage. The resistance to the ground should be measured to provide the condition of insulation dielectric strength. The surge test simulates the starting characteristics of the surge which helps us to detect whether the insulation is in good condition or not depending on the surge test waveforms.
The breakdown of insulation between turns can cause unbalanced magnetic fields and theses result in vibration, buzzing, excessive heating, degradation of insulations and bearing failure. A slot paper is placed between different phases in the same slot in order to prevent leakage between the phases. A test to show the location where the phase winding is shorted to the ground is shown in Figure 8.

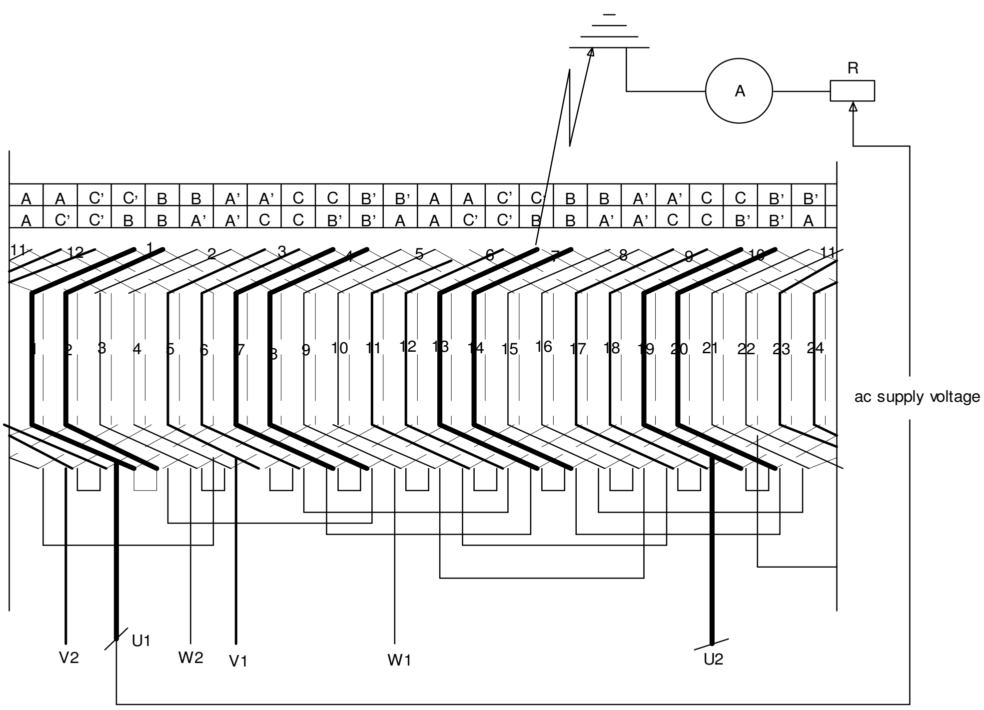

Fig. 8: Location of the shorted phase winding to the ground

When the stator winding is star connected and there is a turn-to-turn short as shown in Figure 9, there will be two low-inductance readings and one-high inductance reading, when considering the phase-to-phase inductance.

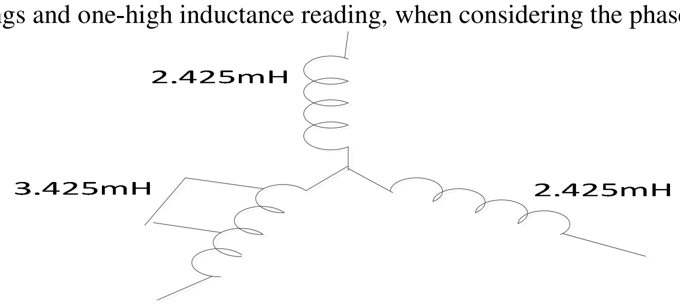

Fig. 9: Star connection

As the stator winding is delta connected, as in Figure 10, a turn-to-turn short results in one-low inductance reading and two-high inductance readings, as the phase-to-phase reading inductance is taken.

 

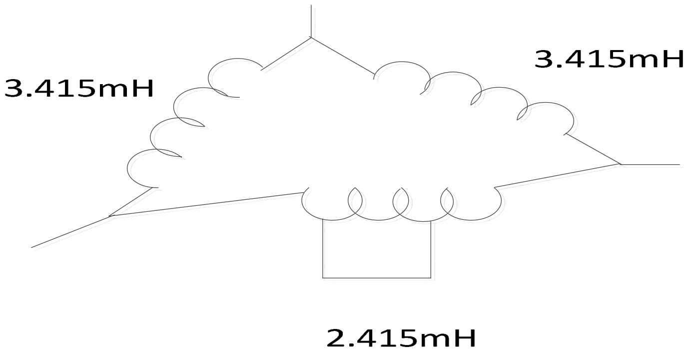


Fig. 10: Delta connection

**1.1.3 Rotor core**

The rotor must be properly checked to ensure there is no broken rotor bar that can cause excessively heating due to loose rotor bars, skewing in the field flux which is generated by the rotor bars and around the rotor bars. The Rotor Influence Test if available can be used as a method of testing rotor condition. There will no displaying of skewing or erratic inductance patterns in the simulation of good rotor bar. Motor shows increase vibration due to the nonalignment of motor shaft with the drive shaft, bent shaft, poor laminations and lubrication [7].

**1.1.4 Air gap**

The air gap which is the space between the stator and the rotor can be made distorted if there is improper mounting of motor to its bedplate. The increased in levels of vibration as a result of uneven magnetic pull creates between the circumference of the rotor and stator bore causes air gap eccentricity. Mechanical vibration causes bearing failure, seize shaft and overheat windings leading to the robbing of the stator and rotor.

**Result and Discussion**

Accurate diagnostic procedure of electric motor with these available technological devices leads to the discovery of fault zones of unhealthy motors with their unusual characteristics and waveforms. Electrical maintenance personnel can repair or replace the damaged parts where necessary which restore the motor to good health. Physical inspection and the uses of megohmeter in troubleshooting of faulty motor is not a true assessment of the motor health. As a preliminary step in troubleshooting or diagnostic situation, look at the whole picture. And do not take a quick decision. Break the system down into its individual fault zones, test each fault zone clearly with every technology available to you, and finally make your recommendations using the terminology for fault zone analysis to express your confidence and capabilities.

**References**

[1] Fluke Corporation. (2003). Three-phase Motors. American Technical Publishers, Inc. 2nd edition, pp. 1-3, U.S.A.
[2] Udo Elger, November (2004).. AC Motors. D48455, Bad Bentheim, Bentheim 3rd. Germany. http://www.rig-electric.com pp.32-33
[3] Jonny Douglass, Motor Repair Specifications (1999) Washington State University Cooperative Extension Energy Program WSUEEP9905. pp. 1-25.
[4] Allen-Bradley, AC Induction Motor. August 2001, 1329M-UM001B-EN-P. www.rockwellautomation.com pp. 10-12. U.S.A.
[5] Sumathi, A, Balasubramanian, P, Krishnakumar, R, Nagarajan, S, (2011). Electical Machines and Appliances Theory, Tamilnadu Textbook Corporation. Chennai. 1st edition, pp. 160-162.
[6] Atablektov V.B (1979). Repair of Electrical Appliances. USSR
[7] Tom Bishop, 2003, Squirrel Cage Rotor Testing, 2003 EASA Convention, Moscone Convention Centre, San Franscisco, CA, pp. 1-26