International Journal For Technological Research In Engineering
Volume 1, Issue 9, May-2014 *ISSN (Online): 2347 - 4718*

COMBINATION OF PLC AND VFD BASED AUTOMATIC DETECTION AND RECTIFICATION OF UNDER VOLTAGE PROBLEM IN 3 PHASE INDUCTION MOTOR

K. Kaviarasu[1], S. Saipadhma[2], P. Arulmani[3]
Department. of Electrical and Electronics Engineering
Thangavelu Engineering College, Chennai, India.

Abstract: Protective functions of an induction motor are mainly intended to prevent overheating of its windings. Owing mainly to overloads or unbalanced voltages, there is increase in consequent overheating of the windings. The PLC operates and switches on the variable frequency drive, which in turn drives the motor with required speed by varying the frequency. The detection of the under voltage fault and disconnection of a faulty section or apparatus can be achieved by using over load relay in conjunction with circuit breakers. It performs both detection and interruption functions automatically but its use is limited for the isolation of motor from supply during high negative sequence current when under voltage will occur. A combination of PLC and VFD method is proposed in this paper. The combination of PLC and VFD is an efficient approach used for getting continuous running of the motor even under conditions of under voltage with Reduced Space, Energy saving, Modular Replacement, Easy trouble shooting, Error diagnostics programmer, Economical, Greater life and reliability. The simulation result shows that the proposed methods outperforms than the other existing approach.
Keywords: Induction motor, unbalanced voltages,

I. INTRODUCTION

Voltage unbalance combined with under- or over voltage is a voltage quality problem. The mentioned phenomenon can be found in a three phase power system commonly. Different factors cause unbalanced voltage in power system including unbalanced loads, incomplete transposition of transmission lines, open-Y, open-Δ transformer connections, blown fuses on three-phase capacitor banks and etc. The induction motors are widely used in industrial, commercial and residential applications and most of them are connected directly to electric power distribution system (PDS). Therefore it is very important to clarify the effect of voltage unbalance on the performance of IM (Hirotsuka et al., 2006) [1]. The unbalanced voltages induces negative sequence current and mentioned current produces a backward rotating field in addition to the forward rotating field produced by the positive sequence one. The interaction of these fields produces pulsating electromagnetic torque and ripple in velocity [2, 3]. Such condition has severe impacts on the performance of an induction motor. The influence of unbalance on the efficiency (Lee, 1999) [4], increase of losses, and the negative effects on the insulation life (Gnaci´nski, 2008) [5], temperature rise, and life reduction (Pillay and Manyage, 2006) [6], derating in the machine (Anwari and Hiendro, 2010) [7] are some contributions in this area. Protection of an induction motor (IM) against possible problems, such as overvoltage, over current, overload, over temperature, and under voltage, occurring in the course of its operation is very important, because it is used intensively in industry as an actuator. Induction motors can be protected using some components such as timers, contactors, voltage, and current relays. This method is known as the classical method that is very basic and involves mechanical dynamic parts. Computer and Programmable Integrated Circuit (PIC) based protection methods have eliminated most of the mechanical components. However, the computer-based protection method requires an analog-to-digital conversion (ADC) card, and the PIC-based protection method does not visualize the electrical parameters measured. In this study, for IMs, a new protection method based on a programmable logic controller (PLC) has been introduced. In this method, all contactors, timers, relays, and the conversion card are eliminated. Moreover, the voltages, the currents, the speed, and the temperature values of the motor, and the problems occurring in the system, are monitored and warning messages are shown on the computer screen. Experimental results show that the PLC-based protection method developed, costs less, provides higher accuracy as well as safe and visual environment compared with the classical, the computer, and the PIC-based protection systems

- The motor goes to off state when the under voltage problem occurs.
- The output power and efficiency of the motor drops drastically when the motor is disconnected during under voltage problem.

In the proposed system, during the under voltage condition, the three phase induction motor runs continuously from the single phase supply with required speed by employing a variable frequency drive. The amount of power the motor draws is roughly related to the product of voltage and current (amps). Thus, when voltage gets low, the current must get higher to provide the same amount of power. The fact that current gets higher is not alarming unless it exceeds the nameplate current rating of the motor. When current value goes above its rated value, it is safe to assume that the buildup of heat within the motor will become damaging if it is left unchecked. Low voltage can cause high currents and overheating which will subsequently shorten motor life. Over load protection relay is used to detect the negative sequence current which occurs during the under voltage condition and it is used to isolate the motor from supply and also gives the signal to PLC. The PLC operates and switches on the supply to the motor through VFD which is fed by single phase supply. Thus the motor runs with required speed safely and PLC switches on the bypass contactor which is used to avoid the return current to the three phase line. The VFD controls the speed of the motor by varying the supply frequency with constant v/f ratio.

II. METHODOLOGY

The overall system block diagram is shown in figure 3.3 which contains following blocks, they are given below. Protective functions of an induction motor are mainly intended to prevent overheating of its windings. Owing mainly to overloads or unbalanced voltages, there is increase in consequent overheating of the windings**.** Three-phase voltage unbalance has long been a problem in power system. In fact, the large-scale negative sequence currents in induction motor results in poor performance. This high current is sensed by the over load relay. Overload relay is connected in three phase line which is used to isolate the motor from line and to give signal to PLC when the current value is greater than its rated value. The PLC operates and switches on the variable frequency drive, which in turn drives the motor with required speed by varying the frequency.

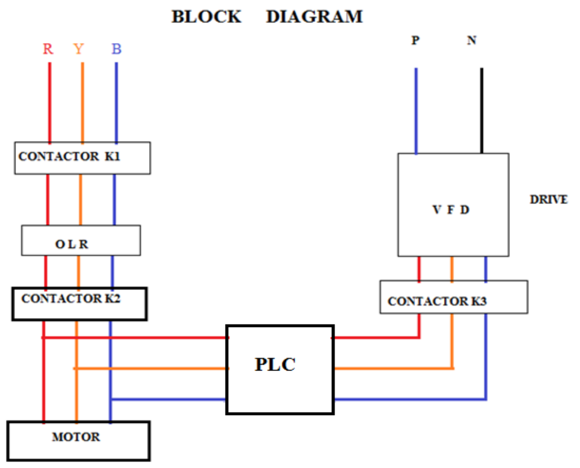


Figure 1: Overall Proposed Block diagram

A. Use of Relay

A simple electromagnetic relay consists of a coil of wire wrapped around a soft iron core, an iron yoke which provides a low reluctance path for magnetic flux, a movable iron armature, and one or more sets of contacts (there are two in the relay pictured). The armature is hinged to the yoke and mechanically linked to one or more sets of moving contacts. It is held in place by a spring so that when the relay is de-energized there is an air gap in the magnetic circuit. In this condition, one of the two sets of contacts in the relay pictured is closed, and the other set is open.

B. Contactor – Design and Construction

Like a relay, a contactor also has

1. Contact
2. Spring
3. Electromagnet

The contact part of the contactor includes the power contacts as well as the auxiliary contacts. The power contacts gains the power for the contactor and the auxiliary contacts is used to bring a loop with the rest of the rest of the devices it is attached to. These contacts are connected to the contact springs. The contacts are controlled by the electromagnet. These electromagnets give the initial force to the contacts and make them closed. Both these contacts and electromagnet are enclosed in a frame which is usually made of insulating materials. The usually used insulating materials are Nylon 6, thermosetting plastics and so on. They are useful, as they completely insulate the contacts and help in preventing the touch of contacts. For high-end contactors, an open-frame contactor is commonly used. This will provide a greater protection from oil, dust, weather and also from explosion. The type of frame housing used may also differ according to the voltage rating used. The ones given above are restricted up to a certain voltage. If the contactors are used to manage volts higher than 1000 volts, inert gases and also vacuum is used as frame housing. Contactors are also used in DC circuits. For their use in DC circuits, magnetic blowouts are also used. The use of blowout coils help in stretching and moving the electric arc. The electric arcs can be AC or DC. An AC arc will have can be easily extinguished as they have low current characteristics. DC arcs of the same current characteristics need more stretching need more current to be blown out. They ratings differ from about 500 Amperes to about 1500 Amperes. In order to save power in a contactor when it is closed, an economizer circuit is also introduced. This circuit helps in reducing the coil current. There is difference in the amount of power that is required to close the contactor and that from keeping it closed. Greater power is required to close it. This circuit will also help it to stay cooler. Take a look at the diagram given below.

C. VFD system

A variable frequency drive system generally consists of an AC motor, a controller and an operator interface.

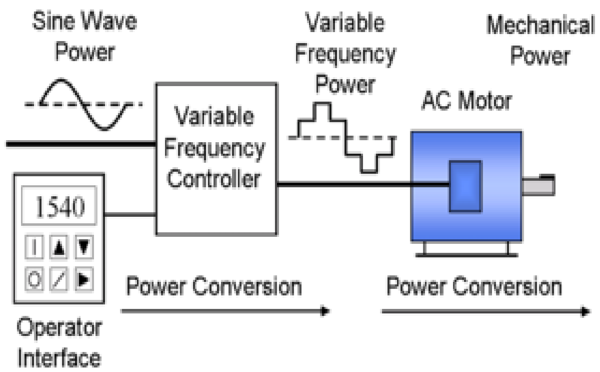


Figure 2: VFD system description

1. Motor

The motor used in a VFD system is usually a three-phase induction motor. Some types of single-phase motors can be used, but three-phase motors are usually preferred. Various types of synchronous motors offer advantages in some situations, but induction motors are suitable for most purposes and are generally the most economical choice. Motors that are designed for fixed-speed operation are often used. Elevated voltage stresses imposed on induction motors that are supplied by VFDs require that such motors be designed for definite-purpose inverter-fed duty in accordance to such requirements as Part 31 of NEMA Standard MG-1.

2. Controller

Variable frequency drive controllers are solid state power electronics conversion devices. The usual design first converts AC input power to DC intermediate power using a rectifier or converter bridge. The rectifier is usually a three-phase, full-wave diode bridge. The DC intermediate power is then converted to quasi-sinusoidal AC power using an inverter switching circuit. The inverter circuit is probably the most important section of the VFD, changing DC energy into three channels of AC energy that can be used by an AC motor. These units provide improved power factor, less harmonic distortion, and low sensitivity to the incoming phase sequencing than older phase controlled converter VFD's. Since incoming power is converted to DC, many units will accept single-phase as well as three-phase input power (acting as a phase converter as well as a speed controller); however the unit must be derated when using single phase input as only part of the rectifier bridge is carrying the connected load.

3. Operator interface

The operator interface provides a means for an operator to start and stop the motor and adjust the operating speed. Additional operator control functions might include reversing, and switching between manual speed adjustment and automatic control from an external process control signal. The operator interface often includes an alphanumeric display and/or indication lights and meters to provide information about the operation of the drive. An operator interface keypad and display unit is often provided on the front of the VFD controller as shown in the photograph above. The keypad display can often be cable-connected and mounted a short distance from the VFD controller. Most are also provided with input and output (I/O) terminals for connecting pushbuttons, switches and other operator interface devices or control signals. A serial communications port is also often available to allow the VFD to be configured, adjusted, monitored and controlled using a computer.

4. *Operation*

When a VFD starts a motor, it initially applies a low frequency and voltage to the motor. The starting frequency is typically 2 Hz or less. Thus starting at such a low frequency avoids the high inrush current that occurs when a motor is started by simply applying the utility (mains) voltage by turning on a switch. After the start of the VFD, the applied frequency and voltage are increased at a controlled rate or ramped up to accelerate the load without drawing excessive current. This starting method typically allows a motor to develop 150% of its rated torque while the VFD is drawing less than 50% of its rated current from the mains in the low speed range. A VFD can be adjusted to produce a steady 150% starting torque from standstill right up to full speed. Note, however, that cooling of the motor is usually not good in the low speed range. Thus running at low speeds even with rated torque for long periods is not possible due to overheating of the motor. If continuous operation with high torque is required in low speeds and external fan is usually needed. The manufacturer of the motor and/or the VFD should specify the cooling requirements for this mode of operation. In principle, the current on the motor side is in direct proportion to the torque that is generated and the voltage on the motor is in direct proportion of the actual speed, while on the network side, the voltage is constant, thus the current on line side is in direct proportion of the power drawn by the motor, that is U.I or C.N where C is torque and N the speed of the motor (we shall consider losses as well, neglected in this explanation).

- n stands for network (grid) and m for motor
- C stands for torque [Nm], U for voltage [V], I for current [A], and N for speed [rad/s]

Neglect losses for the moment

- Un.In = Um.Im (same power drawn from network and from motor)
- Um.Im = Cm.Nm (motor mechanical power = motor electrical power)
- Given Un is a constant (network voltage) we conclude: In = Cm.Nm/Un that is "line current (network) is in direct proportion of motor power".

With a VFD, the stopping sequence is just the opposite as the starting sequence. The frequency and voltage applied to the motor are ramped down at a controlled rate. When the frequency approaches zero, the motor is shut off. A small amount of braking torque is available to help decelerate the load a little faster than it would stop if the motor were simply switched off and allowed to coast. Additional braking torque can be obtained by adding a braking circuit (resistor controlled by a transistor) to dissipate the braking energy. With a 4-quadrant rectifier (active-front-end), the VFD is able to break the load by applying a reverse torque and reverting the energy to the network.

5. Application considerations

Motor bearing currents

PWM drives are inherently associated with high frequency common mode voltages and currents which may cause trouble with motor bearings. When these high frequency voltages find a path to earth through a bearing metal transfer or electrical discharge machining (EDM) sparking occurs between the bearing's ball and the bearing's race. Over time EDM-based sparking causes erosion in the bearing race that can be seen as a fluting pattern. In large motors, the stray capacitance of the windings provides paths for high frequency currents that pass through the motor shaft ends leading to a circulating type of bearing current. Poor grounding of motor stators can lead to shaft ground bearing currents. Small motors with poorly grounded driven equipment are susceptible to high frequency bearing currents. Prevention of high frequency bearing current damage uses three approaches: good cabling and grounding practices, interruption of bearing currents, and filtering or damping of common mode currents. Good cabling and grounding practices can include use of shielded, symmetrical-geometry power cable to supply the motor, installation of shaft grounding brushes, and conductive bearing grease. Bearing currents can be interrupted by installation of insulated bearings and specially designed electrostatic shielded induction motors. Filtering and damping high frequency bearing currents can involve installation of filters, lowering of carrier frequency, or using VFD with 3-level (instead of standard 2-level) inverter topology. Since inverter-fed motor cables' high frequency current spikes can interfere with other cabling in facilities, such inverter-fed motor cables should not only be of shielded, symmetrical-geometry design but should also be routed at least 50 cm away from signal cables.

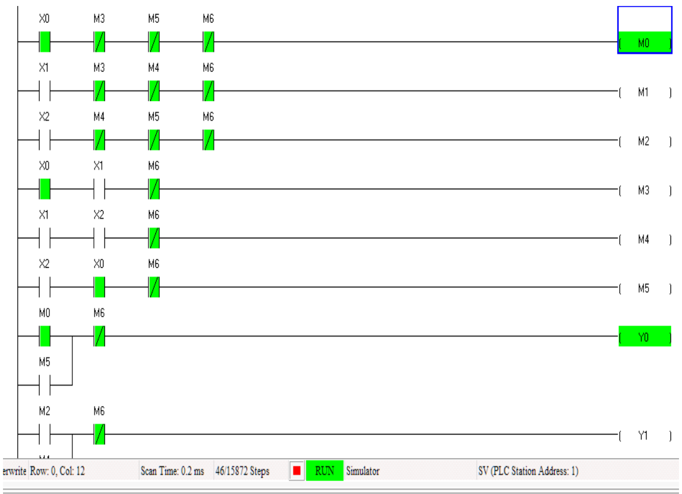
Dynamic braking

Using the motor as a generator to absorb energy from the system is called dynamic braking. Dynamic braking stops the system more quickly than coasting. Since dynamic braking requires that the rotor be moving, it becomes less effective at low speed and cannot be used to hold a load at a stopped position. During normal braking of an electric motor, the electrical energy produced by the motor is dissipated as heat inside of the rotor, which increases the likelihood of damage and eventual failure. Therefore, some systems transfer this energy to an outside bank of resistors.

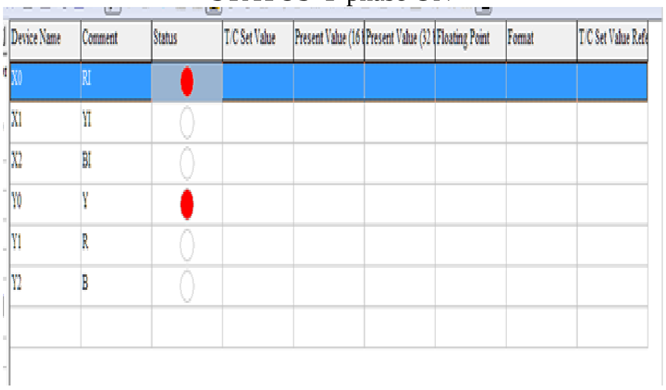
III. SIMULATION RESULTS

IV.

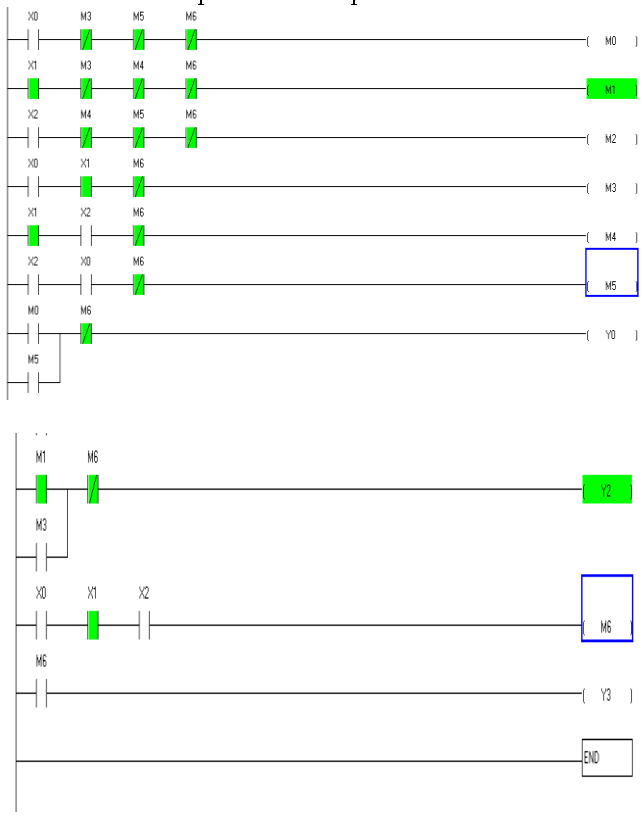
CONDITION 1: R-phase OFF Y-phase ON



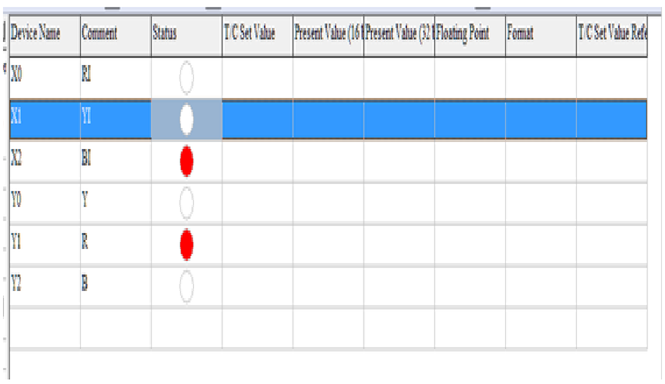
STATUS-Y phase ON



CONDITION 2: Y-phase OFF B-phase ON



STATUS-B Phase ON



IV. CONCLUSION AND FUTURE SCOPE

The detection of the under voltage fault and disconnection of a faulty section or apparatus can be achieved by using over load relay in conjunction with circuit breakers. It performs both detection and interruption functions automatically but its use is limited for the isolation of motor from supply during high negative sequence current when under voltage will occur. The combination of PLC and VFD is thus used for getting continuous running of the motor even under conditions of under voltage with Reduced Space, Energy saving, Modular Replacement, Easy trouble shooting, Error diagnostics programmer, Economical, Greater life and reliability, the Compatibilities of PLC'S, Logic Control, PID control, Operator control, Signaling and listing, Coordination and communication. Here in this research, controlling a single motor with the combination of PLC and VFD is proposed. In future this can be extended to control more number of motors with the single PLC. Also we can monitor and control the operation of motor through remote operation in Human Machine Interface (HMI) with Programmable Logic Controller (PLC).

REFERENCES

[1] Hirotsuka, I., K. Tsuboi, and F. Ueda, 2006. New Calculation Method and Characteristics for the Induction Motor under Unbalanced Voltage Condition. Institute of Electrical Installation Engineers of Japan, 26(3): 215–219.
[2] Alwash, J.H.H. and S.H. Ikhwan, 1995. Generalized approach to the analysis of asymmetrical three phase induction motors. IEE Proceedings Electric Power Applications, 142(2): 87-96.
[3] Smith, A.C. and D.G. Dorrell, 1996. Calculation and measurement of unbalanced magnetic pull in cage induction motors with eccentric rotors. I. Analytical model. IEE Proceedings Electric Power Applications, 143(3): 193- 201.
[4] Lee, C.Y., 1999. Effects of Unbalanced Voltage on the Operation Performance of a Three-phase Induction Motor. IEEE Transactions on Energy Conversion, 14(2): 202-208.
[5] Gnaci´nski, P., 2008. Windings Temperature and Loss of Life of an Induction Machine under Voltage Unbalance Combined with over or under voltages. IEEE Transactions on Energy Conversion, 23(2):363-371.
[6] Pillay, P. and M. Manyage, 2006. Loss of Life in Induction Machines Operating With Unbalanced Supplies. IEEE Transactions on Energy Conversion, 21(4): 813 822.
[7] Anwari, M. and A. Hiendro, 2010. New Unbalance Factor for Estimating Performance of a Three-Phase Induction Motor With Under and Overvoltage Unbalance. IEEE Transactions on Energy Conversion, 25(3): 619-625.

