PHASE FAILURE DETECTOR AND THEIR SIGNIFICANCE IN POWER SYSTEM ENGINEERING

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ABSTRACT

Electrical power system engineering comprises power generation, transmission, distribution, and the utilization of electricity. Modern trends in the development of electric power systems explore means of improving efficiency in these stages mentioned. On the demand side, the protection of consumer equipment and appliances from damage and total destruction due to phase failures is an issue of paramount importance mainly in parts of the world with unsteady supply of electricity. In this work we took a detailed look into what a phase failure is and the possible causes. Then we finally explain the details of a method we have developed that detects cases of phase failure and takes the appropriate measure that will save the consumer loads from damages.

Keywords: Power System; Phase failure; Detector; Power outage; Power protection

INTRODUCTION

After the generation and distribution of electricity, if it is not well managed by the final consumer, there could be losses and serious problems to the loads and user alike. With the recent increase in the use of power in our homes and industries, there is the need to adequately protect our homes, industries and every other appliance that make use of electricity. Thus a phase failure detector is overly important both for the improvement of the quality of service from the power utility companies and the protection of life and properties of the electricity consumers.

The concept of Phase Failure

This is a situation where any of the three phases in a power system fails. This could result from a fuse blowing up or an interruption in the power line. Phase failure could be caused by any of the following:

a. Unbalanced voltage
b. Single phasing or phase loss
c. Overloads
d. Power outage (short cycling, over cycling)
e. Overvoltage
f. Under-voltage
g. Phase reversal (incorrect phase sequence)

Unbalanced Voltage

When the voltages are unbalanced, the measured line-to-line and the average voltages are different. Deviation is the difference between any one line-to-line voltage and the average of all three voltages. When the voltages are balanced, the line-to-line voltages and the average voltage are equal. Any voltage unbalance results in a current unbalance that is 6 to 10 times the voltage unbalance. This unbalanced current flows as eddy currents; causing the overheating of the windings. If an unbalanced condition exists, the nameplate horsepower rating must be de-rated to prevent overheating of the windings.

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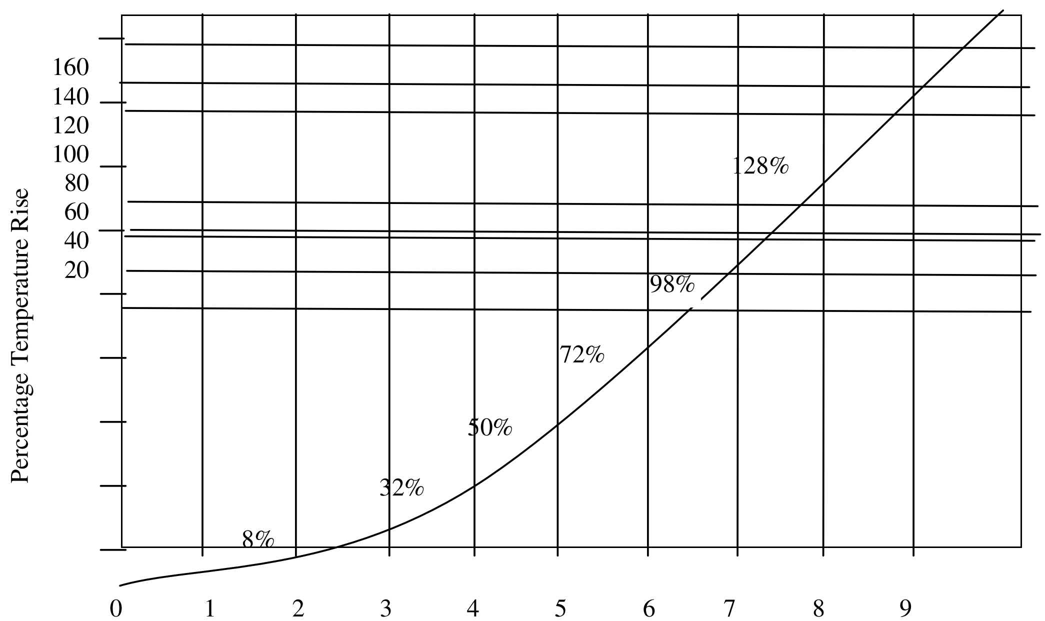
A three phase motor operating in an unbalanced circuit, cannot deliver its rated horsepower. With 3% voltage unbalance, a motor can produce 90% of its rated horsepower without overheating. Operation of a motor when the unbalance exceeds 5% is not recommended because when the unbalanced voltages exceed 5%, the temperature rise is so fast that protection by de-rating is not practical.

Example:	3%	Unbalance	=	18%	Overheating
	5%	Unbalance	=	50%	Overheating
	7%	Unbalance	=	98%	Overheating

Overheating caused by unbalanced voltages



Percentage voltage unbalance

Voltage Unbalance Example:

Measured Voltages

Phase A-B	224
Phase B-C	205
Phase C-A	195
Average Voltage	208

Difference from the Average

VA	:	224-208	=	16
VB	:	205-208	=	3
VC	:	195-208	=	13

The largest deviation is used to calculate the percentage of voltage unbalance:

Voltage Unbalance = *Largest Deviation* / *Average Voltage x 100*

Voltage Unbalance = *16* / *208 x 100*

= *7.7%.*

Voltage unbalance is the most difficult to detect and therefore, often overlooked. Motor failures caused by voltage unbalance and are often misdiagnosed as being damaged by phase loss. Unless moderate unbalance can be monitored, phase loss with motor running, may not be detected.

Single phasing or phase loss

Single phasing or phase loss is the operation of a three phase motor on only two phases to due to the loss of voltage on one phase. Phase loss is the maximum condition of voltage unbalance. This occurs when one fuse blows, when there is a mechanical failure within the equipment, a broken power line, open supply transformer winding, or a lightning strike.

Overloads

An *overload* is caused by the application of excessive load to a motor. This excessive load exceeds the FLA (Full Load Amps) rating of the motor causing it to draw more current and therefore, produce damaging excessive heat in the windings.

Power outage (short cycling, over cycling)

Most power outages are 1 to 3 seconds (this is not the case in Nigeria) long and are often accompanied by low voltages or brownouts. The utilities' re-closing the breaker will make three attempts to clear the lines. This process can result in short cycling. Short cycling is the repeated act of turning on and off a device in a short duration of time. Remember, during startup, a motor draws 600% of nameplate current. The motor must operate or sit idle until the normal temperature is reached. Most motors are designed to be started less than 10 times per hour. Short cycling can cause excessive heat and winding failure.

Phase Reversal (Incorrect Phase Sequence)

When the connections of any two phases in a three phase power supply are reversed, this phase reversal will not affect heater or resistive loads but, a three phase motor will run backward. This condition is destructive to rotation sensitive equipment such as elevators, screw and scroll compressors, centrifugal pumps, and conveyors

Under voltage:

Under voltage is an average line-to-line voltage that is lower than the minimum acceptable operating voltage for the equipment in use. Per NEMA standards, induction motors should be capable of delivering their nameplate load rating when subjected to (Balanced) under voltage of -10% of the motors nameplate value. Voltage variations below 90%, of the nameplate rating, may cause overheating and winding insulation failures. When the voltage is low, the starting current increases dramatically. Under-voltage increases motor slip and difficulties in motor startup.

PHASE FAILURE DETECTOR

The phase failure detector under consideration in this work is an electro-mechanical device used in power system engineering to protect a load from damage due to a failure in any of the phases supplying power to the load. It automatically cuts off the load from the supply if one of the individual phase conductors becomes faulty. A phase failure detector is particularly important component in many assembly plants using the mains power supply. In such assemblies, the total loss of power in a phase of the mains supply or a significant reduction in its value due to uneven load conditions will cause serious problems.

Examples of other systems requiring phase failure detectors include power supplies for three-phase motors, transformers, and rectifiers. A more prominent example is the rectifier solutions in which a semi-controlled thyristor bridge is used. It is important that even short network breaks are detected to ensure that control of the bridge does not continue in diode mode once mains voltage has been restored. This is because intermediate circuit voltage can occur during an outage, resulting in fuses blowing when the power supply voltage is restored, and leading to a break in the operation of a process. Phase failure detector can thus be used in many different industrial applications, in ships,

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and in a national power supply network. They prevent damage to load if one of the individual phases is interrupted.

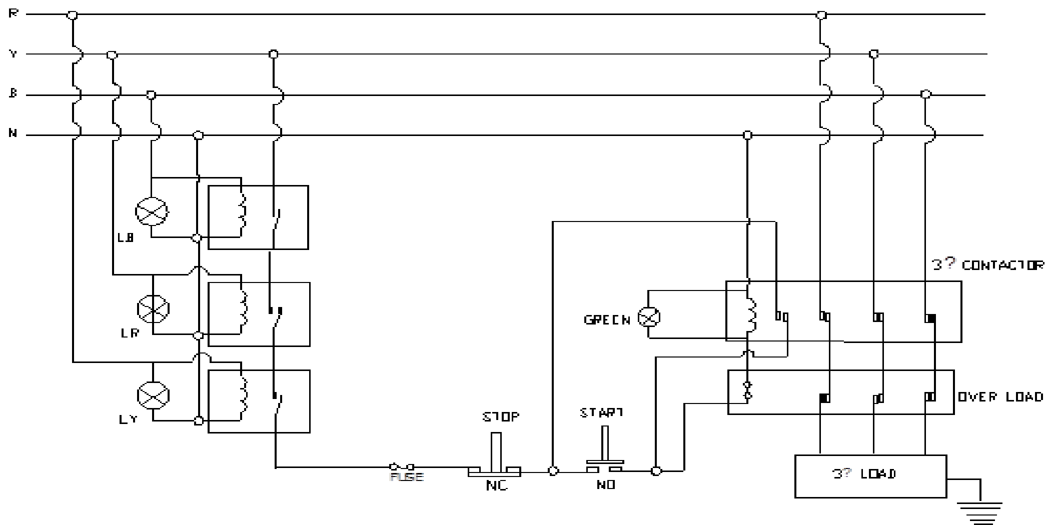

Figure 1. A Phase Failure Detector Circuit Diagram

MODE OF OPERATION OF THE PHASE FAILURE DETECTOR

The Phase failure detector is an automatic system designed specifically to monitor failure in any of the phases of the mains supply. The system incorporates three a.c relays, a fuse, one normally open and one normally closed push button switch, a three-pole contactor with a normally open auxiliary contact and a three phase overload mechanism. The relays all form the control unit while the contactor and push button switches make up the tripper. Whenever the control unit detects any phase failure it cuts off power to the tripper which upon tripping off, disconnects the load from the mains supply. The overload mechanism protects the load from overload, while in addition to the fuse, protects the circuit from over current.

The control unit monitors the three phases. Each relay in the control unit is connected between a phase and neutral- relay 1 is to blue phase, relay 2 to yellow phase, while relay 3 is linked to red phase. These phases control the switching of the relays. When the system is powered and with voltage present in all the phases, the three relays are energized and their contacts which are connected in series closes thereby transferring voltage to the start button. At the same time the corresponding indicators come on showing the phases with power. The stop button is a normally closed push button switch while the start button is a normally open push button switch. When the start button is pressed it completes the circuit, hence, the contactor coil is powered through the normally closed contact of the overload mechanism, thus, the contactor is energized and its contacts close. In a like manner, the auxiliary contact of the relay closes. Power is hence transferred to the load from the contactor through the overload mechanism. The green indicator comes on indicating power has been delivered to the load. Since the contactor auxiliary contact is in parallel with the start switch and is closed- it maintains the flow of current even after the start switch has been released. Pressing the stop button causes an open circuit, thus, disrupting current flowing to the contactor coil. This de-energizes the contactor which in turn cuts off power to the load as its contacts open. On the other hand, if a phase fails its associated relay is de-energized causing an open circuit just as experienced with the stop button. This equally de-energizes the contactor and hence cuts off power to the load. In addition, if a phase voltage drops so much it will not be able to energize the relay this leads to the same result as experienced with phase failure. Furthermore, if overload occurs the normally closed contact of the overload mechanism opens and again disrupts power to the coils of the contactor. The contactor contacts will open cutting off power from the load. If the load were to be a three phase motor, at each time the contactor is de-energized, the motor is switched off and it stops running. By this means the motor is protected from damage or malfunction.

The major components for the design of a phase failure detector shown above are the contactor and AC relay shown in the diagrams below.

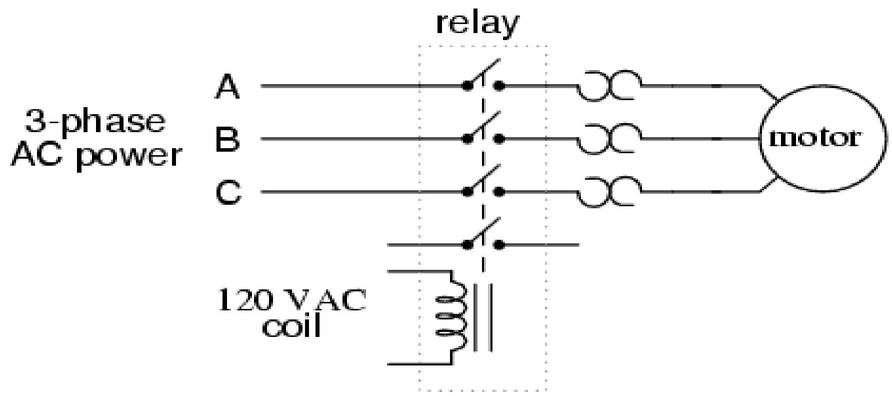

Figure 2. AC relay

A Contactor Circuit Diagram

A basic contactor will have a coil input (which may be driven by either an AC or DC supply depending on the contactor design). The coil may be energized at the same voltage as the motor, or may be separately controlled with a lower coil voltage better suited for the control. Certain contactors have series coils connected in the motor circuit; these are used, for example, for automatic acceleration control, where the next stage of resistance is not cut out until the motor current has dropped.

Operating Principle of the Contactor

Contactors are designed to be directly connected to high-current load devices. Relays tend to be of lower capacity and are usually designed for both Normally Closed and Normally Open applications. Devices switching more than 15 amperes or in circuits rated more than a few kilowatts are usually called contactors. Apart from optional auxiliary low current contacts, contactors are almost exclusively fitted with Normally Open contacts. Unlike relays, contactors are designed with features to control and suppress the arc produced when interrupting heavy motor currents. When current passes through the electromagnet, a magnetic field is produced which attracts ferrous objects, in this case the moving core of the contactor is attracted to the stationarity core. Since there is an air gap initially, the electromagnet coil draws more current initially until the cores meet and reduce the gap, increasing the inductive impedance of the circuit. The moving contact is propelled by the moving core; the force developed by the electromagnet holds the moving and fixed contacts together. When the contactor coil is de-energized, gravity or a spring returns the electromagnet core to its initial position and opens the contacts.

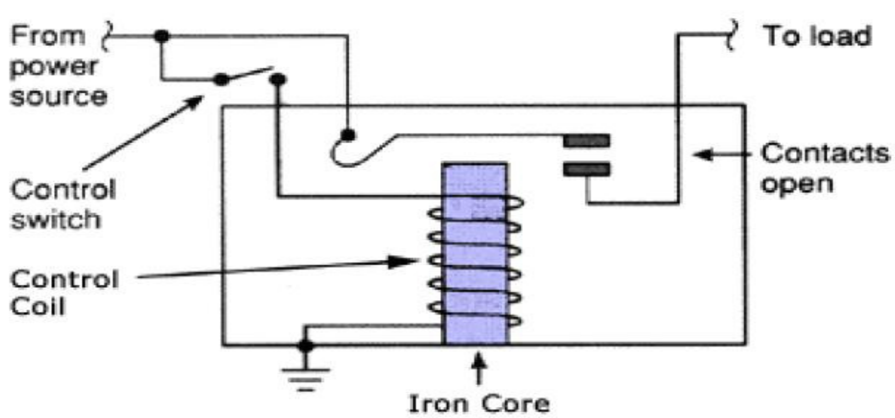

Figure 3. A simple design of a relay

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CONCLUSION

In conclusion, this presentation has shown that a good and reliable phase failure detector can be designed locally and that there is the need for a phase failure detector in our industries and homes. Since phase failure cannot be avoided in our everyday electricity consumption, it is paramount to note that phase failure detector is a very vital protective device that must be taken seriously. The Nigeria government should take interest in the production of this phase failure detector instead of the importation.

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