GROUND CHECK MONITORS FOR UNDERGROUND POWER SYSTEMS

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Since the introduction of electricity into the mining industry we have had to live with the hazard of electrical shock. Through the years we have had miners electrocuted due to energized frames of equipment which were assumed to be harmless.

Although the power systems which supplied power to the equipment were designed with proper grounding, to prevent electrocution, in many cases the grounding systems were altered, resulting in systems which powered the equipment but provided no protection for the men against energized frames.

The Federal Coal Mine Health and Safety Act of 1969 included provisions for eliminating the hazard of electrical shock due to improperly grounded equipment. These are outlined in Title 30 CFR Parts 75.803 and 75.902. Under these provisions it is required that high, medium, and low voltage resistance grounded systems include a fail safe ground check circuit.

The requirements for ground wire monitoring have been in effect since September 30, 1970. They cover all resistance grounded circuits in underground coal mines. The only exception has been with monitoring of trailing cables in the face area.

The basic principle of operation of monitors at the time Sections 75.803 and 75.902 were written is shown in figure 1. The technique used was to pass current down the pilot wire to the equipment frame and back up the ground wire. It was believed that if the ground wire should become broken, the current would stop and the monitor could trip the circuit breaker.

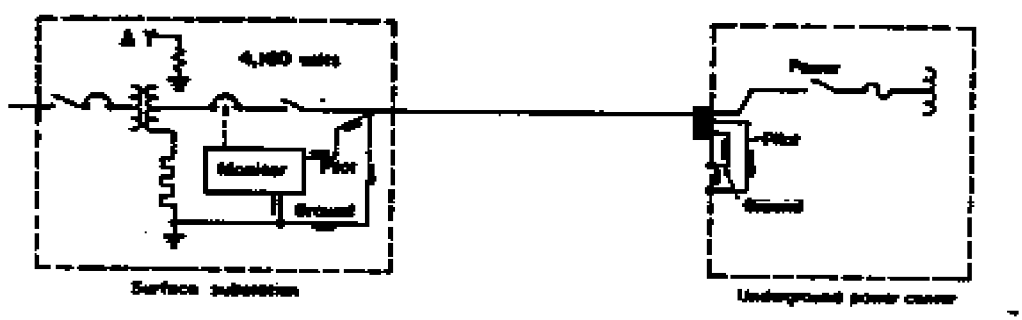

Figure 1. Basic Operating Principle

The condition which we are trying to protect against is shown in figure 2. This figure depicts a phase to ground fault while the ground wire is broken. In this situation if there is no monitor, or if the monitor is not working properly, the power center frame will be energized to approximately 2400 volts. In addition, all the equipment being supplied power from the power center will also be elevated to 2400 volts. This electrical shock hazard can be eliminated with a properly operating monitor circuit.

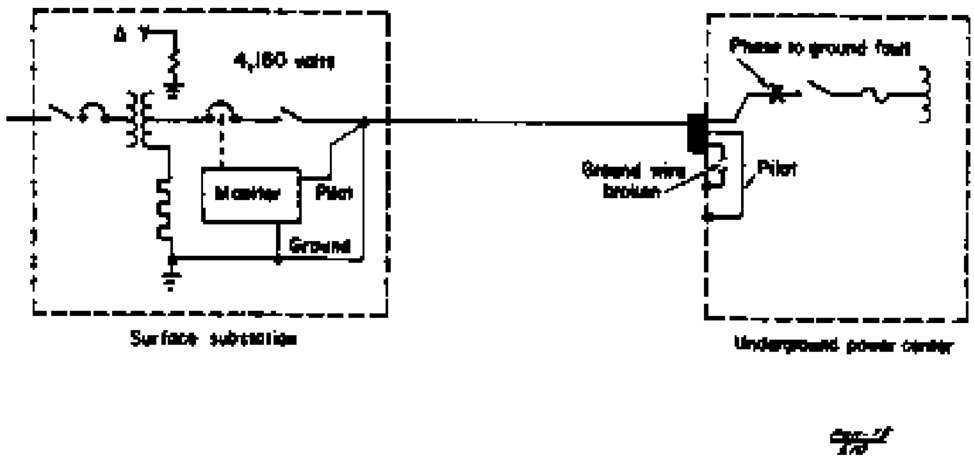

Figure 2. Hazardous Condition

TWO BASIC APPROACHES TO MONITORING

There are two basic types of monitors. These types are referred to as “pilot wire” and “wireless”.

An example of the pilot wire type is shown in figure 1. It uses the pilot wire, which is usually in the power cable, to carry the monitoring current to the frame of the equipment which is having its ground wire monitored.

An example of a wireless monitor is shown in figure 3. The wireless types usually employ all of the power conductors to perform the function of the pilot wire. On advantage of the wireless monitors is that existing cables without pilot wires can be used on equipment being monitored. This particular type of properly designing the frequency in the audio range for monitoring. By properly designing the filters denoted by and “F” in figure 3, the audio frequency can be placed on and taken off the power conductors without any adverse interaction with the power center.

FACE EQUIPMENT MONITORING

Wire type monitors that will monitor both low and medium voltage face equipment are commercially available. Some mines have been using these without any operational problems for well in excess of a year.

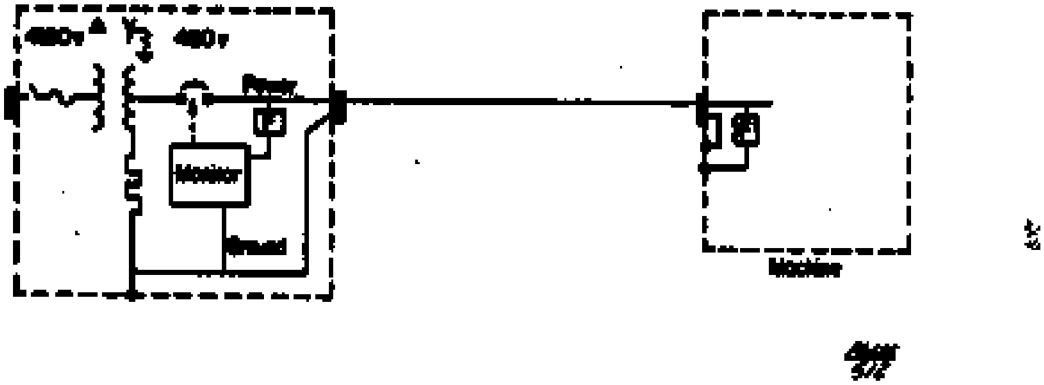

Figure 3. Typical Wireless Monitor

In an effort to determine the availability of reliable and functional wireless ground monitors, MESA Technical Support offices in Beckley and Pittsburgh conducted a nine month survey in conjunction with the Bureau of Mines. In this survey six monitors were purchased from each of the four manufacturers who were marketing ground monitors for face equipment. The monitors were placed on operating sections in pairs of the same type. In order to obtain experience with the monitors on low and high coal mining equipment, the monitors were also distributed in coal seams that varied in height from 30" to 6'. These mines were located in Kentucky, Ohio, Pennsylvania, Virginia, and West Virginia.

The survey was conducted by using event counters to count monitor trips and power outages. In this manner accurate data were obtained on how many times the monitors signaled a broken ground wire.

The data were analyzed to see if, in fact, all the monitors performed in the mining environment as the regulations require. In addition, as the monitors were installed they were checked to make sure no intermachine arcing was present.

It was learned from the survey that the monitors were very sensitive to voltage dips and signaled an excessive number of trips when the ground wires were in fact not broken. The survey had led to design changes in some of the monitors. It is interesting to note that none of the monitors used contributed to arcing between the machines. As a result of this work and other research efforts, wireless monitoring of face equipment will be possible in the near future.

PROBLEMS ASSOCIATED WITH MONITORING

Intermachine Arcing

When ground wire monitoring was first instituted, it was thought to be causing arcing between machines such as loaders and shuttle cars. Because of the arcing problem monitoring of face equipment was suspended until the problem could be investigated and solutions found.

After several research efforts by the Bureau of Mines and investigations by MESA, the problem of intermachine arcing has been solved. This problem was found to have many sources of which ground monitoring was only one. Such devices as saturable reactors and diode packs have been designed to eliminate the intermachine arcing problem.

The introduction of diode and saturable reactor type of arc suppressors used in conjunction with ground monitor circuits for face monitoring has made it possible to safely monitor ground wires in cables of face equipment.

Stray Currents

In coal mines where track haulage systems are used one of the major stumbling blocks to monitors is stray D.C. currents. A close look at figure 4 will give some insight into this problem.

As a trip passes by the area where the water pipe contacts the track, part of the return current enters the pipe and flows to the sump pump, through the monitoring circuit, through the high voltage cable ground wire and back to the rectifier. This current has been measured in excess of 10 amperes and most of the time it is large enough to cause false tripping of monitors in circuits of this type.

Voltage Regulation

Many mine power systems are suffering from overexpansion. The systems were originally designed to handle a specified load but due to expansion of the mine, i.e., adding additional sections, higher horsepower motors, etc., the power system has become "soft". When this situation exists the result is poor voltage regulation. It is not uncommon for the voltage at some mines to fluctuate as much as 25% below normal. This magnitude of voltage fluctuation has caused the best of the monitor systems to trip the breaker. At least one manufacturer has designed around this problem by using a battery to supply power to the monitor during such voltage dips.

Parallel Paths

One of the most difficult problems to deal with when trying to monitor ground conductors is that of parallel paths. Figure 5 depicts a situation in which parallel paths make it impossible to determine if the grounding conductor is broken. Should the ground conductor come loose or break at points A or B the monitor current would flow from the surface monitor to the power center via the pilot wire. The current would then return through the ground wire to rectifier "B", through the rectifier case to the track, to rectifier "A", then back into high voltage cable groundwire, and back to surface monitor. Although this situation makes detection of the broken groundwire nearly impossible, it is a blessing in disguise. Just the fact that it is hard to detect the broken wire indicates that the equipment still has some semblance of equipment grounding. The problem then becomes one of determining the quality of this grounding circuit. This grounding circuit could range anywhere from marginal to better than the cable alone would provide.

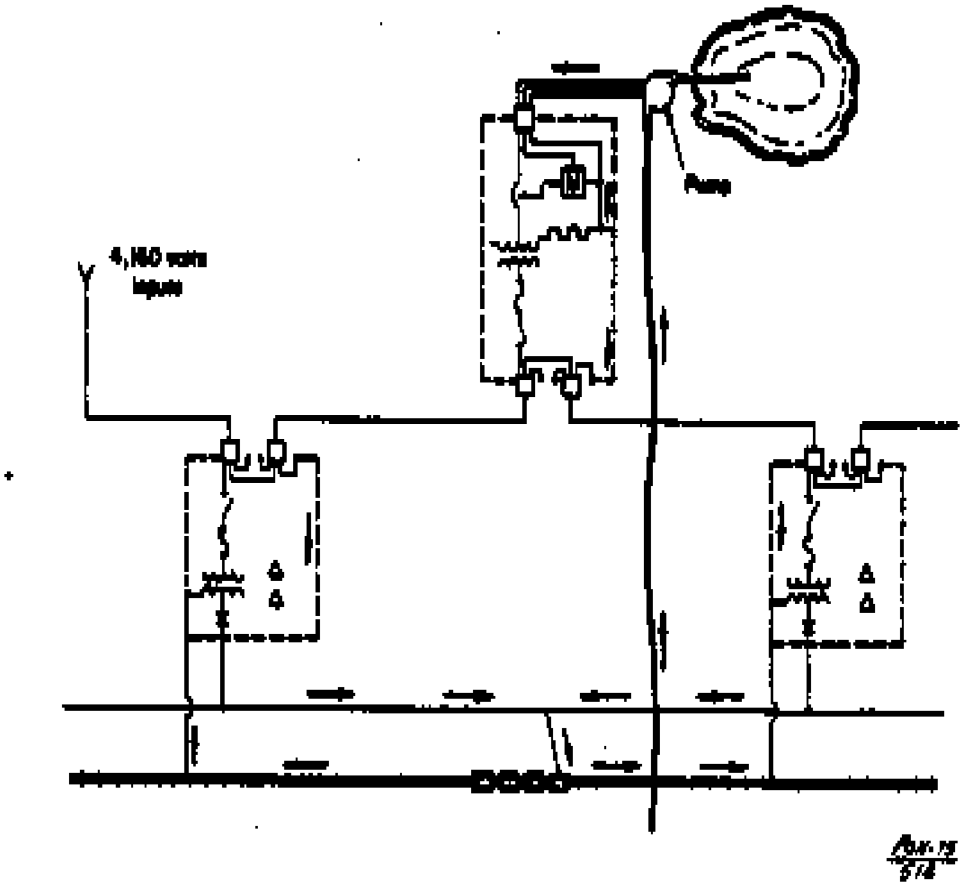

Figure 4. Stray DC Currents

Situations such as this gave birth to the concept of impedance monitoring. This type of monitoring carries continuity monitoring one step further by continuously monitoring the value of the impedance of the grounding circuit as well as establishing its continuity.

When impedance monitoring is used with high voltage circuits the monitor must trip the breaker when the grounding circuit's impedance becomes so large that the fault current would cause more than 100 volts to appear on equipment frames during a ground fault. This requirement in 30 CFR Part 75.801 states: "The grounding resistor, where required, shall be of the proper ohmic value to limit the voltage drop in the grounding circuit external to the resistor to not more than 100 volts under fault conditions".

For example, if the system uses a 25 ampere resistor, the impedance monitor would have to initiate a circuit breaker trip if the grounding circuit exceeded 4.0 ohms.

Impedance monitoring of low voltage circuits is performed in a similar manner as with high voltage circuits. The difference is that the monitor must trip the breaker if the grounding circuit's impedance increases to the point that 40 volts will appear on the equipment frames under ground fault conditions.

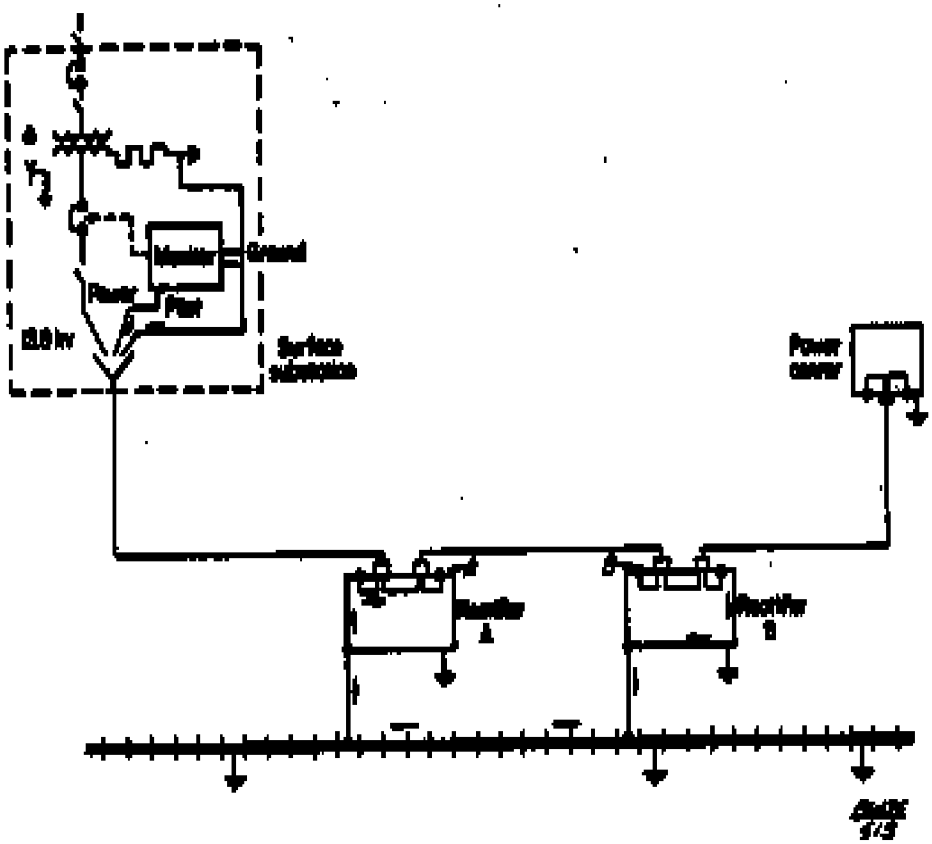

Figure 5. Parallel Grounding Circuits

DESIGN AND PERFORMANCE REQUIREMENTS

When designing a monitor system the following criteria should be kept in mind.

<u>High Voltage Monitoring Systems</u>

1. The ground monitor must trip the circuit breaker when the pilot wire is broken at the extreme end of the circuit.

2. The ground monitor must trip the breaker when either the ground wire is broken at any point in the grounding circuit or when the impedance of the grounding circuit increases beyond the amount necessary to cause a 100 volt drop in the grounding circuit external to the grounding resistor under fault conditions.

3. The maximum voltage that can be used on ground check circuits cannot exceed 96 volts.

4. During normal operation the relay contacts must be closed when the relay is energized.

5. There must be no intentional time delay built into the ground check circuit other than that necessary to allow orderly closing of circuit breakers. This time delay should not exceed 0.5 seconds per ground check circuit when several ground check circuits are operating in series and no more than 2.0 seconds time delay maximum on any one system.

6. When the ground check relay is used to provide the undervoltage protection for the system it must trip the circuit breaker when the line voltage decreases to a level of 40 to 60 percent of the nominal line voltage.

7. The pilot wire when used external to the cable must not be smaller than No. 8 (A.W.G.).

8. Couplers used with ground check circuits must be designed so that the pilot wire breaks first when the coupler is separated.

9. The pilot wire and ground wire must be connected to the equipment frames by separate connectors.

Low Voltage Monitoring Systems

1. The ground monitor must trip the circuit breaker when the pilot wire is broken at the extreme end of the circuit.

2. The ground monitor must trip the breaker when either the ground wire is broken at any point in the grounding circuit or when the impedance of the grounding circuit increases beyond the amount necessary to cause a 40 volt drop in the grounding circuit external to the grounding resistor under fault conditions.

3. The maximum voltage that can be used on ground check circuits cannot exceed 40 volts.

4. During normal operation the relay contacts must be closed when the relay is energized.

5. When the ground check relay is used to provide the undervoltage protection for the system, it must trip the circuit breaker when the line voltage decreases to a level of 40 to 60 percent of the nominal line voltage.

6. Couplers used with ground check circuits must be designed so that the pilot wire breaks first when the coupler is separated.

7. The pilot wire and ground wire must be connected to the equipment frames by separate connectors.

CONCLUSION

Since the enactment of the Federal Coal Mine Health and Safety Act of 1969, a great deal of money and effort has been expended to resolve monitoring problems related to high, medium, and low voltage systems. As a result of these efforts the initial stumbling blocks which seemed to make monitoring impossible in certain situations have been removed. Monitors and associated hardware have been developed to eliminate such problems as intermachine arcing, nuisance tripping, and parallel paths.

However, there still exist some unusual cases where caution design of monitoring systems is necessary because of the interaction of several power systems. MESA Technical Support has worked with the mining industry to solve these monitoring problems in the past and will continue to do so in the future.