Ground Wire Monitor
and
Power System Acceptance Program Update

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Abstract

An update and review is presented on the Mine Safety and Health Administration's Monitor and Power Systems (MAPS) program. This program encompasses the acceptance of unconventional ground wire monitor and ground wire device installation arrangements. Since the introduction of the program in June 1991, eleven MAPS acceptances have been issued for installation. Although the MAPS program can be applied to all types of mining equipment and mining methods, the eleven acceptances issued have been on approved longwall electrical power systems. These MAPS accepted GWM/GWD installations may be utilized on other longwall mine power systems exhibiting similar system components. Consequently, a strategically designed MAPS application covering a broad range of equipment operational characteristics may be submitted to MSHA. Following review of the application by MSHA, a MAPS acceptance may be issued which is applicable to other mine power systems.

INTRODUCTION

The Mine Safety and Health Administration's (MSHA) Approval and Certification Center (A&CC) introduced a new application procedure known as the "Monitor and Power System (MAPS) Program", in June, 1991. The MAPS program was developed to augment MSHA's present ground wire monitor (GWM) and ground wire device (GWD - a device inserted in series with a grounding conductor to suppress intermachine arcing or to isolate parallel paths) acceptance procedures. The MAPS application procedure covers the tests, analyses and acceptance criteria for assessing unconventional GWM or GWD installation arrangements or combinations. In most cases, the unconventional GWM/GWD installations were not conceived or evaluated at the time of the original acceptance and therefore were not included under the equipment's acceptance ratings or were not included in the equipment's accepted installation manuals. Examples of such installations may include low/medium voltage rated GWMs or GWDs installed in high voltage power circuits or monitoring a trailing cable which contains a grounded in-line cable coupler or connection box. Although the unconventional GWM/GWD installations differ from the originally accepted installations, they can provide equivalent safety when their operation is coordinated with other electrical power system components. The coordination of the GWM's or GWD's operation with the other electrical power system components is the primary goal of the MAPS program acceptance criteria. This coordination has been successfully achieved on approved longwall mining systems.

MAPS ACCEPTED INSTALLATIONS

At present, eleven GWM/GWD installations have been issued a MAPS acceptance by MSHA's A&CC. Each of these MAPS accepted GWM/GWD installations were designed for use on a specific approved longwall electrical system. These MAPS acceptances provide the mine operators with the flexibility to install, for example, certain low/medium voltage rated GWMs and/or GWDs in 2300 volt power circuits and to install non-isolated in-line cable couplers or connection boxes in shearer and face conveyor cables. In addition to the installation flexibility gained with the MAPS accepted GWM/GWD installations, a MAPS acceptance confirms that the resistance of the grounding circuit should not restrict the ground fault current to quantities less than the trip setting of the ground fault relaying devices.

POWER SYSTEM COMPONENT PARAMETERS

The MAPS acceptances for unconventional GWM/GWD installations are based on evaluations which coordinate the GWM's or GWD's operational characteristics with certain other power system component parameters. The power system component parameter and GWM/GWD operational characteristics used to evaluate the unconventional GWM/GWD installations are listed in Table 1.

TABLE 1 - Parameters and operational characteristics

A. Three (3) phase power transformer voltage (volt)
B. GWM characteristic dropout resistance (OHM)
C. GWD high current test time and current (seconds, Amp)
D. Power transformer phase-to-phase short circuit current (Amp)
E. Total system short circuit clearing time (seconds)
F. System's available ground fault current (Amp)
G. Ground fault relay current trip setting (Amp)
H. Identification of cables containing in-line couplers or connection boxes.

The differences between the proposed EWM/GWD installations and the equipments' original MSHA acceptance ratings or installation instructions were evaluated to determine which component parameters listed in Table 1 are applicable to the MAPS acceptance evaluations. For instance, the MAPS evaluation for a GWM installed in a system to monitor a grounding circuit with a sectionalized cable (a cable containing a grounded in-line cable connection, as shown in Figure l), will involve the GWM's characteristic dropout resistance and the system's available ground fault current. The product of these two parameters are considered the potential equipment frame voltage during a ground fault condition. The magnitude of this product cannot exceed the allowable equipment frame voltages specified in the MSHA Program Policy Manual, Volume 5, under sections 75.803 and 75.902.

The potential equipment frame voltage which may exist during a ground fault condition is illustrated in Figure 2. The grounded connector frame in the sectionalized cable creates a conductive path. This path is parallel to the cable's ground wire between the equipment frame and the cable connector or connection box. If the cable's ground wire becomes severed or disconnected, the parallel path may conduct sufficient GWM signal current to prevent the GWM from detecting the open ground wire. The GWM's inability to detect the open ground wire between the equipment frame and cable connector or connection box may exist until the resistance of the parallel path (R) exceeds the GWM's characteristic dropout resistance. If a ground fault occurred when the ground wire was discontinuous, but the parallel path resistance was slightly less than the GWM's dropout resistance, a potential equipment frame voltage would be created by ground fault current flowing through the parallel path. For the sectionalized cable situations, the MAPS acceptance evaluates that the potential equipment frame voltage should not be greater than 40 volts on low/medium voltage power systems or 100 volts on high voltage power systems,

The MAPS evaluation for a low/medium voltage rated GWD installed in a high voltage power circuit confirms that the high voltage circuit should not subject the GWD to a phase-to-phase short circuit current of greater magnitude and duration than the GWD was subject to during its high current acceptance tests. A situation where a GWD could be subjected to a 3-phase transformer's phase-to-phase short circuit current is illustrated in Figure 3.

The GWD may conduct a phase-to-phase short circuit current when one phase in a power center's plug and receptacle shorts to the plug's metallic shell and a different phase shorts simultaneously to the receptacle's ground pin or the cable's ground wire. The resulting phase-to-phase fault current would conduct through the GWD connected in series with the grounding conductor of the receptacle. The magnitude of the fault current is dependent on the 3-phase transformer's short circuit capacity. The duration of the phase-to-phase fault is dependent on the system's total short circuit or grounded phase protective device operating time. To confirm that a GWD originally accepted for use in low/medium voltage power circuit can withstand the phase-to-phase short circuit of a high voltage transformer, a direct comparison of the GWD's high current test quantities and the capabilities of the system is made.

GENERIC MAPS APPLICATION

The eleven MAPS applications evaluated thus far by MSHA have involved specific descriptions of longwall electrical power systems' layouts and discreet system component parameter quantities. Evaluation of these discreet system component quantities have resulted in MAPS acceptances which can be applied to other electrical power systems. Application of these MAPS accepted GWM/GWD installations to other power systems will be limited to systems with component parameter quantities identical to the discreet quantities covered under the MAPS acceptance evaluation.

For instance, a MAPS evaluation to determine the potential equipment frame voltage occurring in a sectionalized cable GWM installation may involve a single, discreet component parameter quantity. The GWM's characteristic dropout resistance may be 30 ohms, while the system's available ground fault current may be 1.3 amperes. The product of these quantities result in a potential equipment frame voltage of approximately 40 volts. This potential equipment frame voltage meets the MAPS acceptance criteria for low/medium or high voltage electrical systems. The MAPS acceptance for this sectionalized cable GWM installation may, therefore, be applied to low/medium or high voltage electrical systems where the available system ground fault current is 1.3 amperes.

An installation with the 30 ohm dropout resistance GWM, but a 3.3 ampere available system ground fault current would result in a potential equipment frame voltage of approximately 100 volts. This product meets the MAPS acceptance criteria for high voltage electrical systems, but not low/medium-voltage systems. The MAPS acceptance for this installation, therefore, applies only to high voltage electrical systems with an available system ground fault current of 3.3 amperes.

The MAPS evaluation to determine the acceptability of a low/medium voltage rated GWD installed in a high voltage electrical system involves the electrical system's phase-to-phase short circuit current calculated at the power center's receptacle and the system's total elapsed short circuit clearing time.

A low/medium voltage rated GWD subjected to 20 KA for 0.58 sec, 16 KA for 0.87 sec and 5 KA for 9.17 sec during its high current acceptance test could be acceptable for installation in a high voltage electrical system. The acceptance of such an installation depends on whether the high-voltage system's short circuit current/clearing time evaluation point is less than (below and to the left of) the GWD high current test quantity curve shown in Figure 4.

GWMs installed in approved longwall systems to monitor grounding circuits with sectionalized cable, and low/medium-voltage rated GWDs installed in high-voltage electrical circuits have become common. Consequently, MAPS evaluations which consider a system's short circuit current and clearing time or the potential equipment frame voltage during a ground fault condition have also become common. The repeated evaluation of similar GWM/GWD installations and electrical system components could be minimized if the MAPS applications include the broadest range of electrical system components.

STRATEGIC MAPS APPLICATION

A MAPS application submitted to MSHA's A&CC for the evaluation of an unconventional GWM/GWD installation is not required to be a direct representation of an electrical system which will be physically installed in a mine. The application may describe a practical range of electrical system component parameter quantities which may be used. The evaluation of a practical range of system component parameters quantities can result in a MAPS accepted GWM/GWD installation which is more flexible and applicable to a broad range of electrical systems.

Depending upon the proposed GWM/GWD installation, a MAPS application for a GWM installation with a sectionalized cable can specify the range of available system ground fault currents which meet the MAPS acceptance criteria. For example, the 30 ohm dropout resistance GWM could be acceptable for installation in a low/medium voltage sectionalized cable if the available ground fault current system is 1.3 amperes or less. It could also be acceptable in a high voltage sectionalized cable if the available ground fault current is 3.3 amperes or less.

Numerous GWMs could also be covered in a MAPS application for sectionalized cable installations if the specified available system ground fault current satisfies the evaluation for the GWM with the greatest dropout resistance. For example, if GWM-1, GWM-2 and GWM-3 have characteristic dropout resistances of 20 ohms, 35 ohms and 50 ohms respectively, all three GWMs could be accepted for installation in low/medium voltage system with sectionalized cables if the system's available ground fault current is 0.8 amperes or less.

Depending on the proposed GWM/GWD installation, a MAPS application could also specify a maximum phase-to-phase short circuit current and corresponding maximum clearing time which would represent more than one 3-phase transformer and/or short circuit protective device. A MAPS application could also include multiple individual short circuit current/clearing time evaluation points. These maximum evaluation points which meet the MAPS acceptance criteria define the electrical systems in which the subject GWD can be installed. Therefore, the resulting MAPS acceptance could apply to many electrical power systems.

CONCLUSION

This paper outlines how the unconventional GWM/GWD installations accepted by MSHA under the Monitor and Power System (MAPS) program can provide mine operators with installation flexibility. Additionally, it has been shown how these GWM/GWD installations can be applied to numerous power systems. Since the installation's flexibility depends on the application submitted to MSHA for evaluation, the greatest flexibility can be realized when the MAPS application information includes a range of system component parameter quantities and/or multiple GWMs or GWDs.

REFERENCES

1. Application Procedure for Evaluation of Monitor and Power Systems (MAPS), MSHA, Approval and Certification Center, January 1992.

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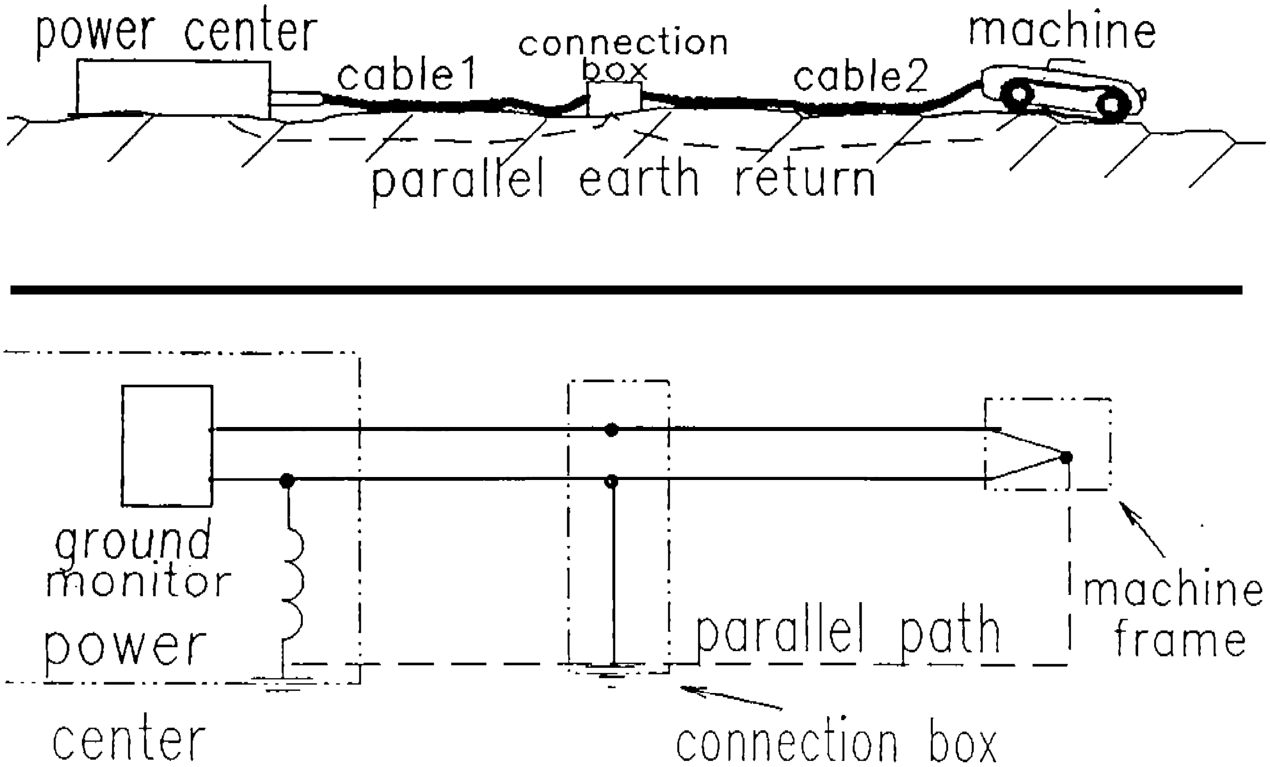

FIGURE 1

Sectionalized cable ground wire monitor circuit using a grounded in-line connection box.

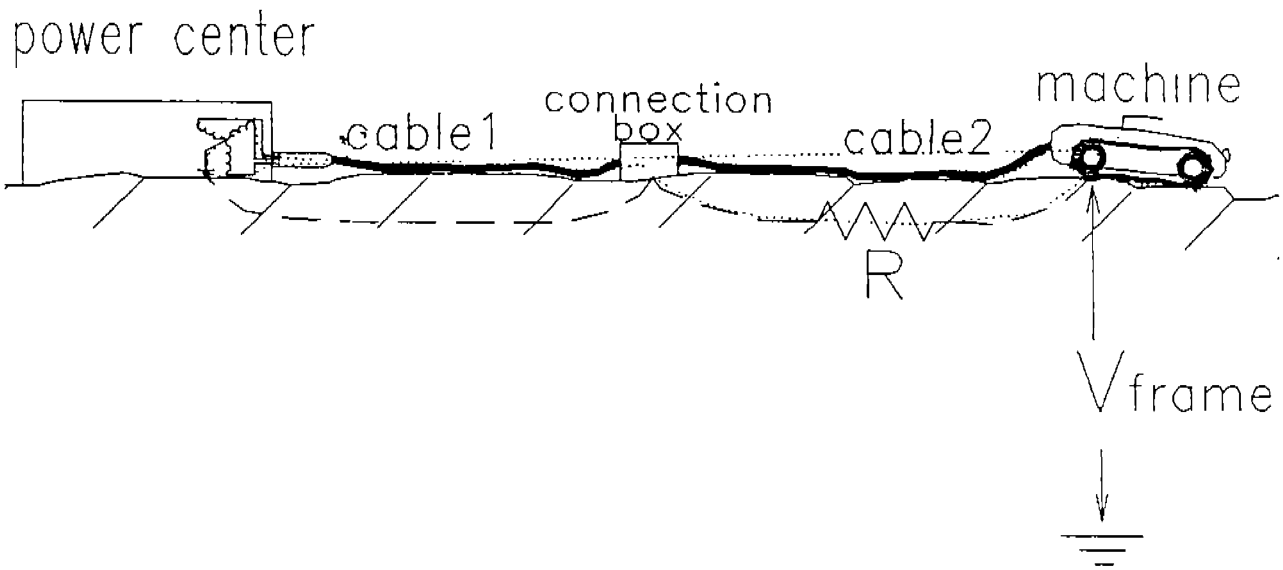

FIGURE 2

Potential equipment frame voltage during a ground fault condition if the ground wire in Cable 2 were possibly severed or disconnected.

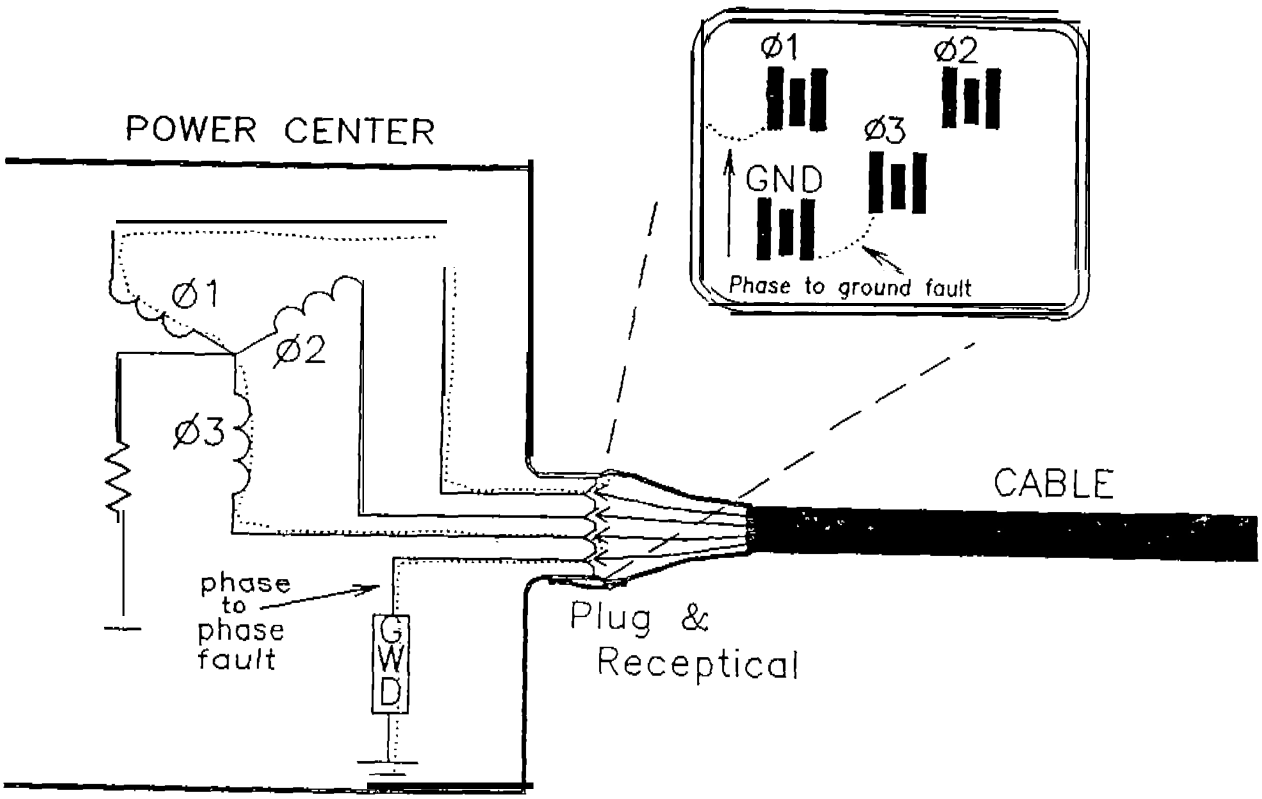

FIGURE 3

Phase-to-phase short circuit which passes through a ground wire device.

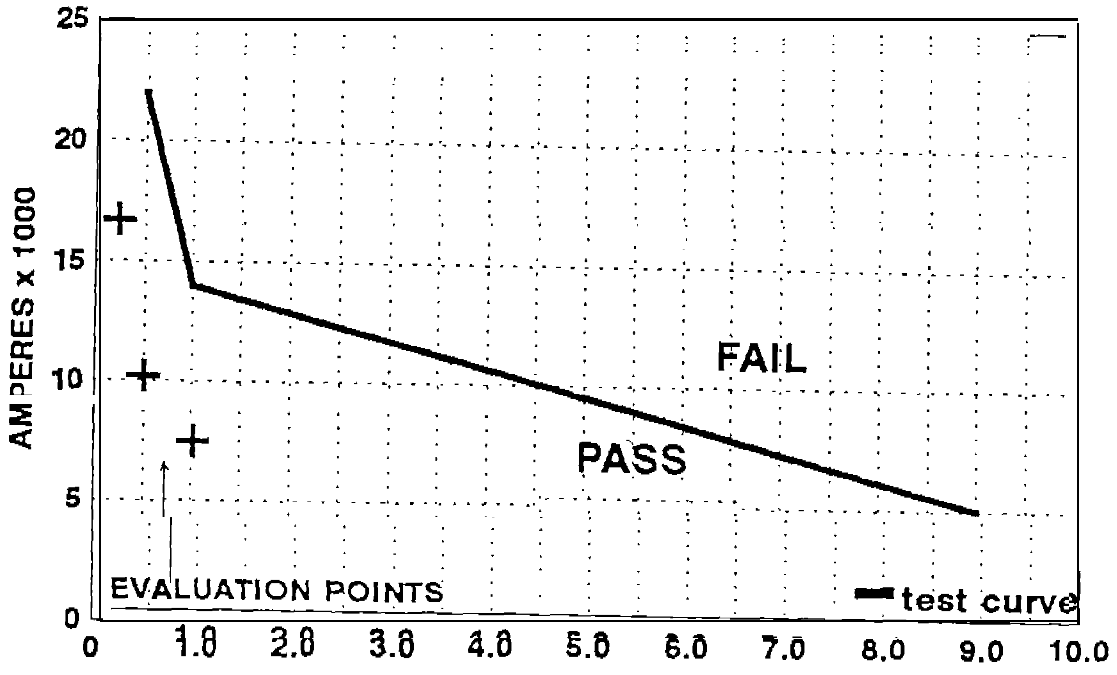

FIGURE 4

Ground wire device high current test quantity curve and power system short circuit current/ clearing time evaluation points.