The Effects of Cable Capacitance on Longwall Power Systems

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Abstract—Utilization voltages used on longwall equipment operating in coal mines in the United States have increased steadily over the past 15 years from 1000 up to 4160 V. This voltage increase has directly influenced the 200% gain in overall longwall productivity from 1987 to the present. The transition from medium voltage (661–1000 V) to high voltage (greater than 1000 V) has permitted significant increases in mining face widths and equipment sizes. Longwall systems with total connected loads of over 5000 hp are now common, and all longwalls in the United States now use high-voltage equipment, with the majority utilizing 4160 V. Shielded cables, which have significantly more capacitance than unshielded cables, are required for high-voltage applications in the mining industry. This capacitance can have detrimental influences on system overvoltages and relay selectivity during ground-fault conditions if the values for the neutral grounding resistor and the ground-fault-relay pickup settings are improperly chosen. These issues are addressed in this paper.

Index Terms—Ground-fault relaying, high-resistance grounding, longwall mining.

I. INTRODUCTION

A NOTABLE increase in the voltage level supplied to longwall mining systems has occurred over the past two decades. Longwalls utilizing 1000 V or less have been phased out over a relatively short time by high-voltage systems utilizing 2400 or 4160 V. The transition to these higher voltages is shown in Fig. 1 [1]–[20]. Prior to 1986, all longwalls in the United States were operated at a utilization voltage less than 1000 V. Fig. 2 shows the individual trends for 2400- and 4160-V systems from 1987 to 2002 [4]–[20]. It is evident from Fig. 2 that 2400-V systems were initially favored over 4160-V

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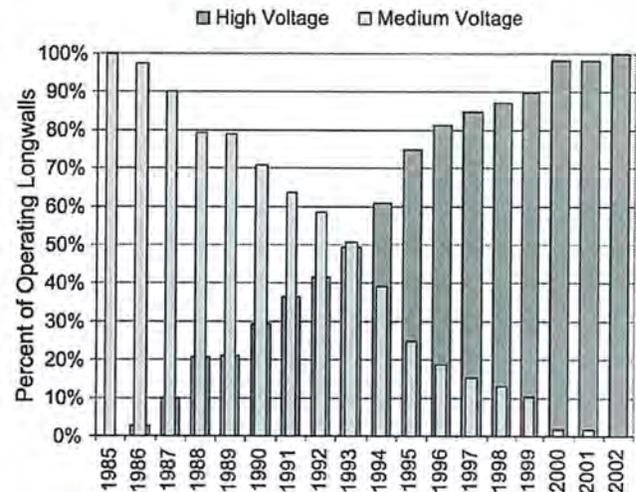Digital Object Identifier 10.1109/TIA.2004.834025

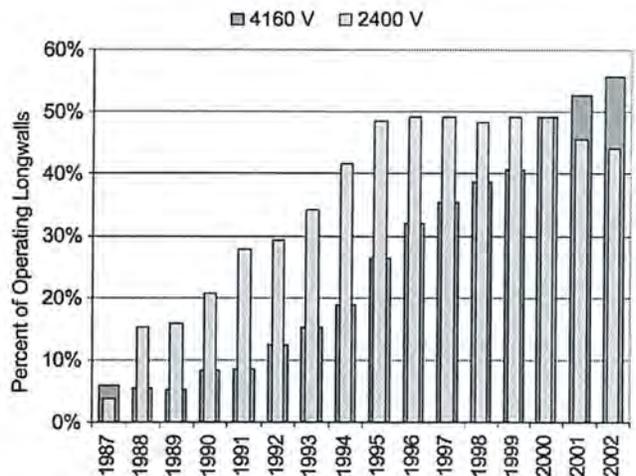Fig. 1. Percentage of longwalls at medium and high voltage.

Fig. 2. Percentage of longwalls at 2400 and 4160 V.

systems. The transition to higher voltages followed a natural progression by taking incremental steps. The 2400-V systems were first implemented as the *next logical step* above 1000 V. As 2400-V machines proved their reliability, they maintained market dominance until 2000. The 2400-V system reached its highest industry utilization in the second half of the last decade. During the early part of this decade, the percentage of longwalls operating at 2400 V began to steadily decline. Conversely, the percentage of 4160-V systems has risen at a steady rate beginning in 1992, and continues today. The

4160-V system took control of the longwall market in 2000 and continued to increase its dominance in 2001 and 2002.

Until March 2002, 30 Code of Federal Regulations (CFR) did not permit the use of high voltage at the mining face. Thus, a mine operator was required to submit a 101(c) Petition for Modification to exploit the benefits of high-voltage utilization on longwall mining equipment. As part of this petition, the Mine Safety and Health Administration (MSHA) initially required a maximum ground-fault resistor current limit (nominal line-to-neutral voltage/resistance of the neutral grounding resistor) of 3.75 A for 4160-V systems and 6.50 A for 2400-V systems [21]. Ground-fault relay pickup settings were not permitted to exceed 40% of the maximum ground-fault current. Shortly thereafter, however, approval of subsequent Petitions for Modification required lowering maximum ground-fault resistor currents to 1.0 A for 2400-V systems and 0.5 A for 4160-V systems, with ground-trip settings of 100 mA [22]–[24]. In earlier papers [25], [26], it was shown that with the long cable runs of a high-voltage longwall, capacitive charging currents could easily exceed these very-low grounding-resistor currents under ground-fault conditions and violate the definition of high resistance grounding. As a result, overvoltages from inductive-capacitive resonance effects are possible [25], and ground-fault relaying selectivity is compromised [26] because of the extremely low pickup setting.

In March of 2002, MSHA eliminated the requirement to file a Petition for Modification by enacting into law an update of the 30 CFR Parts 18 and 75 which now includes provisions for operating high-voltage longwall equipment. Ironically, all longwalls in the U.S. were already operating at high-voltage when this law was enacted. In the new mandatory safety standards, MSHA reversed its position on maximum ground-fault currents and re-established the limits of 3.75 A and 6.50 A for 4160-V and 2400-V systems, respectively. Furthermore, ground-fault protection at the power center must be set at less than 40% of the maximum ground-fault current. However, high-voltage motors and shearers must be provided with instantaneous ground-fault protection set at not more than 0.125 A.

The size of the neutral grounding resistor is analyzed in the subsequent sections for its effects on the operating characteristics for both the 2400- and 4160-V power systems. Recommendations are made for minimizing problems that may occur with overvoltages and relay selectivity due to system capacitance.

II. ANALYSES

Analyses were performed on typical 2400- and 4160-V longwall power systems, which are described in Figs. 3 and 4, respectively. All high-voltage cables for both systems are 5-kV SHD type G-GC. The 2400-V power system shown in Fig. 3 is referred to as an *inby system*, since the motor-starting switchgear is located at the headgate of the longwall, well within 150 ft of the mining face. Because of its location, the switchgear and its associated controls are required to be mounted in an MSHA approved *permissible* (explosion-proof) enclosure. Fig. 3 shows a 5-MVA power center supplied from a 13.8 kV distribution system. The power center is connected to the headgate controller by two parallel 500 kcmil cables, which are supported by a monorail. Typical cable and motor sizes are given in the
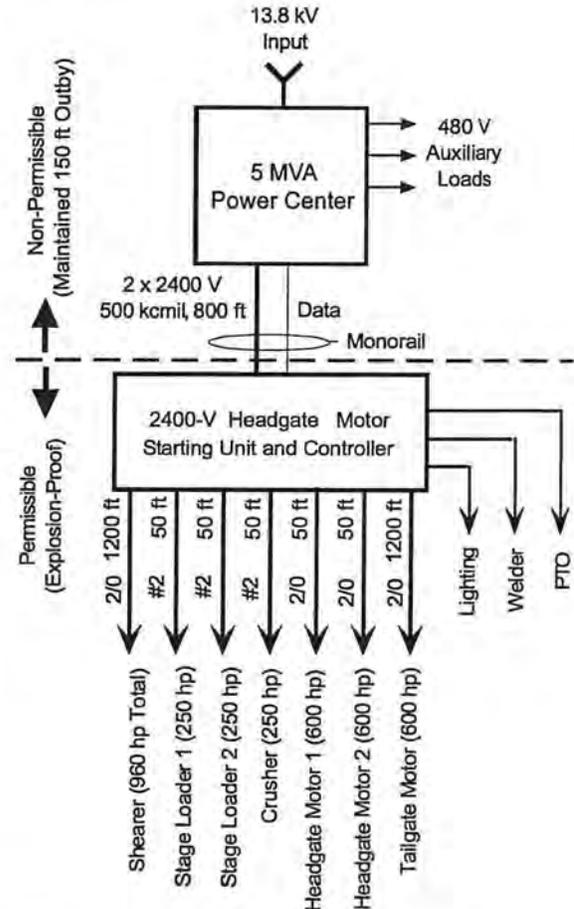

Fig. 3. General arrangement for a 2400-V *inby* power system.

diagram. Cables are often oversized to reduce voltage drop and for standardization purposes.

In contrast to the 2400-V *inby system*, an *outby system* is typically used with 4160 V, and its general arrangement is shown in Fig. 4. The major difference between the two systems is that the motor-staring switchgear of the *outby system* is located near the power center, well over 150 ft (typically over 1000 ft) outby the face. Thus, the switchgear does not have to be housed in an explosion-proof enclosure. Unlike the *inby system*, all motor cables, plus the headgate controller cables, are supported by the monorail cable-handling system.

Zero-sequence ground-fault protection is located in the motor starting units and power centers of both the *inby* and *outby* systems. All outgoing circuits in the motor starting units have instantaneous ground-fault protection. Ground-fault protection is also provided in the power centers and generally has a time delay of 0.25 s to allow coordination with the protection in the motor starting units. As stated previously, the high-voltage longwall regulations now limit the maximum current in the neutral grounding resistor to 6.5 A for the 2400-V system and 3.75 A for the 4160-V system. The maximum pickup setting at the power center is limited to 40% of the maximum current in the neutral grounding resistor. However, the maximum instantaneous pickup setting in the motor-starting units is set at 0.125 A for each outgoing circuit.
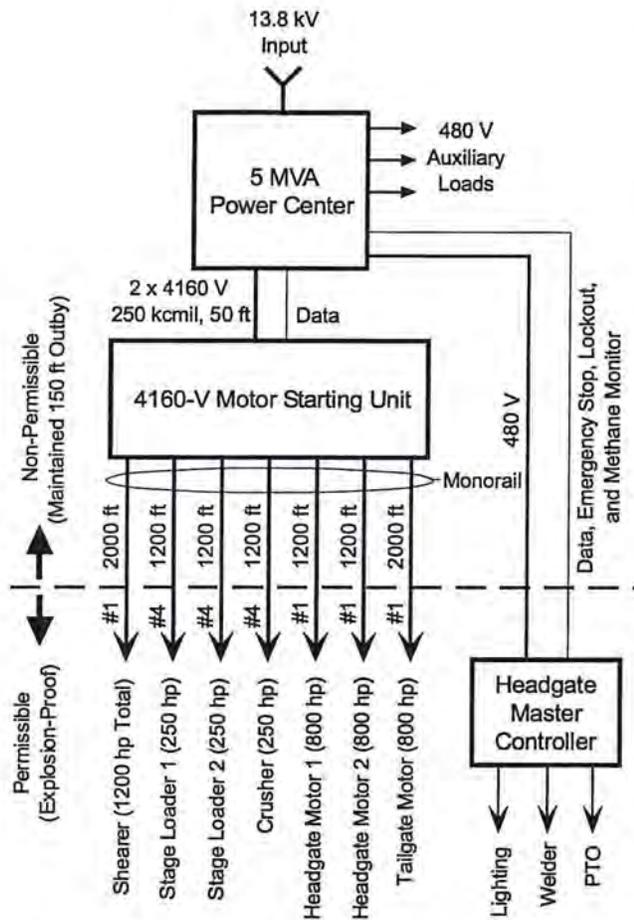
Fig. 4. General arrangement for a 4160-V *outby* power system.

A. Model

The circuit model of Fig. 5 was constructed for performing the simulations using PSpice for both the 2400- and 4160-V systems. Some liberties were taken to simplify the model, but sufficient detail exists to accurately evaluate the grounding systems. The model consists of the longwall equipment motors, power transformer, neutral grounding resistor, and associated cables. All motors are energized and operating at rated conditions for the simulations.

The secondary of the power center transformer is modeled as three voltage sources with series impedances connected in a wye configuration. The voltage sources represent the three-phase line-to-neutral voltages and are phase displaced by 120°. The series impedances are based upon a 5% transformer impedance with an X/R ratio of 4. The neutral grounding resistor (NGR) is shown connected between the system neutral and ground.

The equipment cables are represented as lumped impedances connected in a π configuration. Cable resistances and inductances are based on the cable's size and length [27]. The system capacitance of the model is only due to the cables; capacitance from transformer and motor windings are ignored. Although capacitance is distributed along the cable's entire length, the cable capacitance is lumped and connected from line to ground
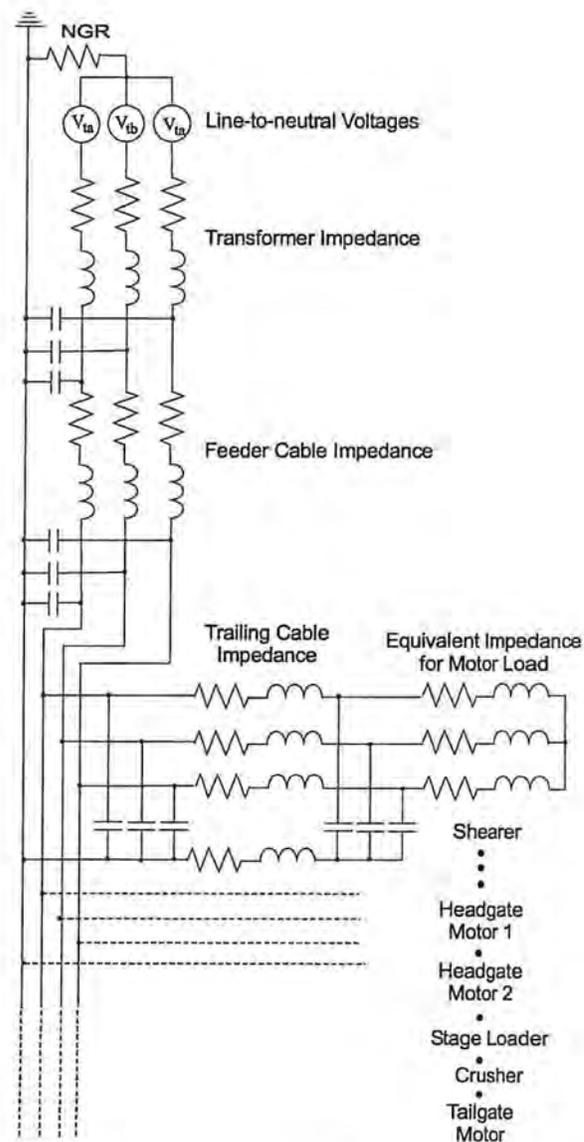

Fig. 5. Generalized simulation model for longwall power systems.

TABLE I
CAPACITANCE FOR 5-kV SHD-GC CABLES

Conductor Size	Capacitance [pF/ft]
500 kcmil	290.9
4/0	221.5
2/0	186.1
#1	160.2
#2	147.0
#4	125.4

at the beginning and end of each cable for simplicity. Cable capacitance per unit length was obtained from a cable manufacturer and is given in Table I [28]. Each motor is modeled with three wye-connected impedances. These impedances are sized to reflect rated conditions with typical power factors and efficiencies.
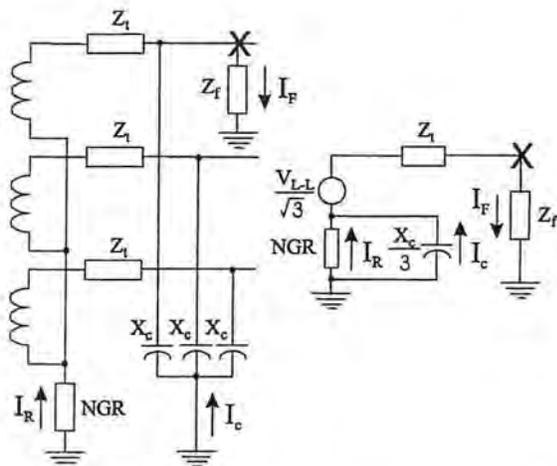
Fig. 6. Simplified representation of a resistance-grounded system with a ground fault.

Fig. 7. Ratio of capacitive charging current to neutral-grounding resistor current for a ground fault with the 2400-V system.

B. Grounding Resistor Results

High-resistance grounding is required in underground coal mining because it limits the amount of energy dissipated and controls the elevation of frame potentials during a ground fault. The intent is to control the maximum ground-fault current by means of the neutral grounding resistor [29], [30]. However, if too high of a value of resistance is used, the system capacitance will become the dominant factor in limiting the fault current. A simplified representation of a resistance grounded system and its single-phase equivalent in Fig. 6 is used to demonstrate this concept. The diagram shows the wye-connected secondary of a three-phase transformer, and its associated impedance (Z_t), with the neutral point tied to ground through the NGR. The per-phase reactance (X_c) due to the inherent cable capacitance is shown connected between each line conductor and ground. A line-to-ground fault occurs through the fault impedance (Z_f). The single-phase diagram shows that the system capacitance is essentially connected in parallel with the neutral grounding resistor. Thus, the fault current (I_F) returns to the source through the system capacitance (I_C) as well as the neutral grounding resistor (I_R).

Standard practice requires high-resistance grounding to be designed so that the capacitive charging current of the system (I_C) is less than or equal to the resistor current (I_R) under a ground-fault condition. The intent of this practice is to prevent the system from developing some of the undesirable characteristics of an ungrounded system. Fig. 6 illustrates how a high-resistance grounded system approaches an ungrounded system as the ohmic value of the grounding resistor increases. Shielded cables, which have significantly more capacitance than unshielded cables, are required for high-voltage applications in the mining industry. Thus, with the long cable runs required by longwall mining, the effects of system capacitance become very pronounced.

Fig. 7 shows the ratio of the capacitive charging current (I_C) to the neutral-grounding resistor current (I_R) with a bolted ground fault for the 2400-V system described in Fig. 3. This ratio is plotted as a function of the ground-fault resistor current
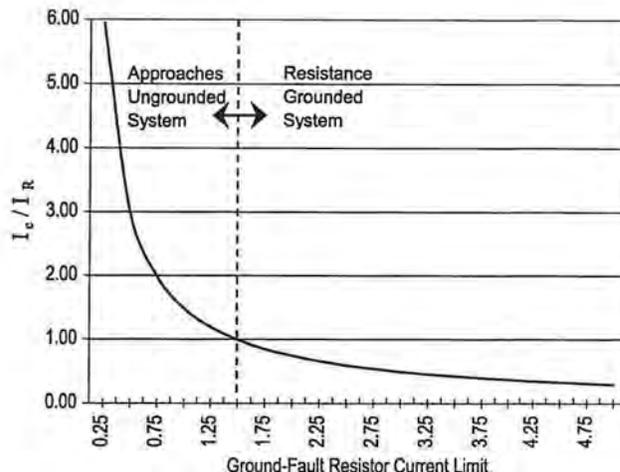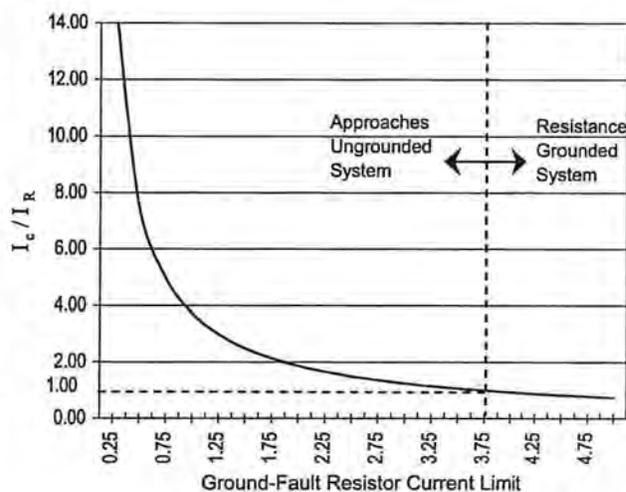

Fig. 8. Ratio of capacitive charging current to neutral-grounding resistor current for a ground fault with the 4160-V system.

limit. By definition, the I_C/I_R ratio should not exceed 1.0. As the ratio increases beyond 1.0, the characteristics begin to approach those of an ungrounded system. It is evident from Fig. 7 that MSHA's old requirement of a 1.0-A ground-fault resistor current results in an I_C/I_R ratio greater than 1.0 and, thus, violates the definition of high-resistance grounding. The present requirement of a 6.5-A limit puts the ratio well within the acceptable range and eliminates overvoltage problems associated with inductive-capacitive resonance, which are discussed later.

Fig. 8 shows the ratio of the capacitive charging current (I_C) to the neutral-grounding resistor current (I_R) for a ground-fault with the 4160-V system described in Fig. 4. Fig. 8 illustrates that MSHA's old requirement of a 0.5-A ground-fault resistor current causes an I_C/I_R ratio of approximately 7, which significantly violates the definition of high-resistance grounding. The 3.75-A limit now required by the new high-voltage regulations coincidently results in a ratio of 1.0, which defines the boundary for high-resistance-grounding.
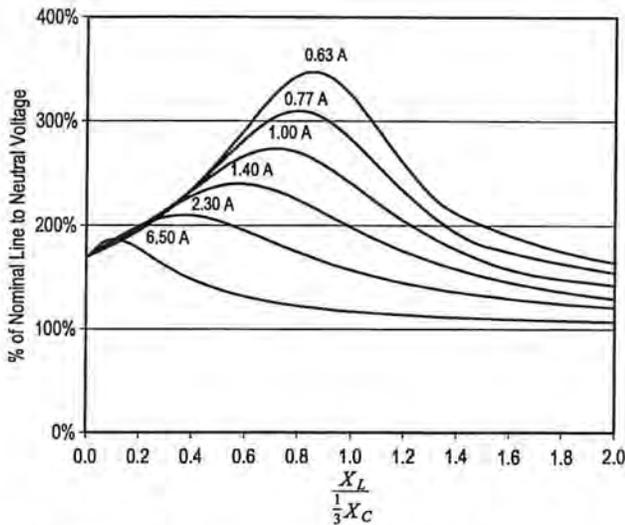
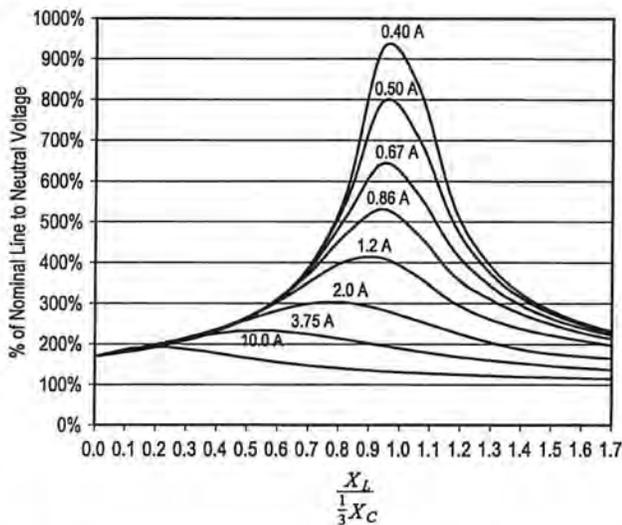Fig. 9.   Worst case resonant overvoltages for the 2400-V system.

Fig. 10.   Worst case resonant overvoltages for the 4160-V system.

The next step in the analysis was to describe the overvoltage characteristics due to inductive-capacitive resonance as a function of the NGR current limit for both the 2400- and 4160-V systems. Therefore, the bolted line-to-ground fault for each system in the previous simulations was replaced with a fault through an inductive reactance to provide a resonant effect with the system capacitance under ground-fault conditions. The total system capacitance can be approximated by adding the individual per-phase lumped capacitances. As a result, the per-phase system capacitance is approximately 0.966 μF for the 2400-V system and 1.38 μF for the 4160-V system. This equates to per-phase system reactances (X_C) of -2.75 kΩ and -1.92 kΩ for the 2400- and 4160-V systems, respectively.

Figs. 9 and 10 illustrate overvoltages under ground-fault conditions for the 2400- and 4160-V systems, respectively. These are worst-case overvoltages since the fault impedance is modeled as a pure inductance. The horizontal axis is the ratio of the inductive reactance (X_L) of the fault to the capacitive reac-

tance $(X_C/3)$ of the system. The vertical axis is given as a percentage of the nominal line-to-neutral voltage, and the ground-fault resistor-current limit is labeled for each curve. A reactance ratio of zero describes a bolted fault; therefore, the line-to-ground voltage is equal to the line-to-line voltage, or 173% of the line-to-neutral voltage. For an ungrounded system, the peak overvoltage occurs at resonance, with a reactance ratio of 1.0. However, the presence of the grounding resistor causes the peak values to shift to the left, as shown in Figs. 9 and 10. As the grounding-resistor-current limit increases, the magnitude of the overvoltage decreases and its peak value occurs at a lower ratio of inductive to capacitive reactance.

Because of the lower voltage and system capacitance, the overvoltage effects are significantly less for the 2400-V system compared with the 4160-V system. Fig. 9 shows that slight overvoltages can occur with MSHA's old ground-fault resistor-current limit of 1.0 A for the 2400-V system, whereas significant overvoltages can arise with the old limit of 0.5 A for the 4160-V system, as illustrated in Fig. 10. The new limits of 6.5 A (2400 V) and 3.75 A (4160 V) represent noteworthy improvements with respect to reducing possible overvoltages. With the 2400-V system, the maximum possible line-to-ground overvoltage is reduced from 280% to 185% of the nominal line-to-neutral voltage. A more striking improvement from 800% to 230% occurs with the 4160-V system.

C. Relay Sensitivity Results

Zero-sequence ground-fault protection is located in both the motor-starting unit and the power center for both voltage levels. All outgoing circuits in the motor-starting unit have instantaneous ground-fault protection. The newly promulgated federal regulations require a maximum pickup setting of 0.125 A for these relays. Ground-fault protection is also provided in the power center and generally has a time delay up to a maximum of 0.25 s to allow coordination with the protection in the motor starting unit. The maximum pickup setting for the power center relay is 40% of the neutral grounding-resistor current.

PSpice simulations were performed with bolted line-to-ground faults at various points in both systems. The neutral grounding resistors were sized to provide 6.5- and 3.75-A ground-fault resistor-current limits for the 2400- and 4160-V systems, respectively. The simulations showed that the 0.125-A pickup setting was far too low to provide selective tripping of the ground-fault relays for both the 2400- and 4160-V systems. As an example, a bolted line-to-ground fault was placed at the output terminals of the power center for both systems. The fault current that the zero-sequence relay would sense for each outgoing circuit was determined. The results for the 2400- and 4160-V systems are presented in Figs. 11 and 12, respectively. Even though the ground faults were located upstream of the outgoing ground-fault relays, the capacitive charging current in conjunction with the low pickup settings caused erroneous tripping of the downstream relays. As expected, Fig. 11 shows that the ground-fault relay located in the power center would detect 6.381 A. However, the ground-fault relays for the shearer and tailgate motors would each sense a current of 0.344 A, which is significantly greater than the 0.125-A trip setting required by Federal Regulations. The relays protecting the shearer and
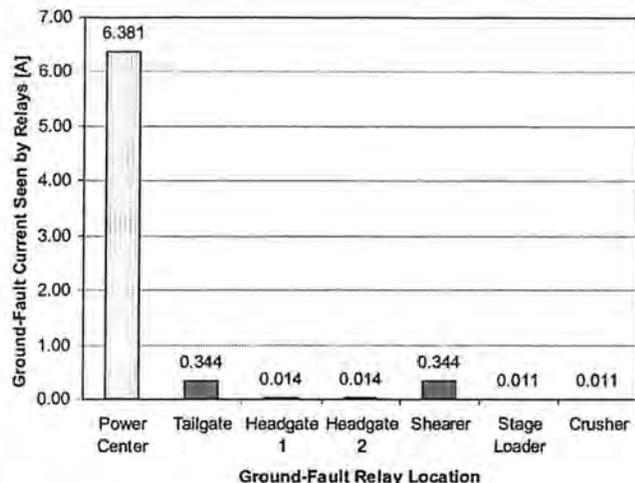
Fig. 11. Currents sensed by ground-fault relays with a bolted line-to-ground fault at the output of the power center for a 2400-V system.
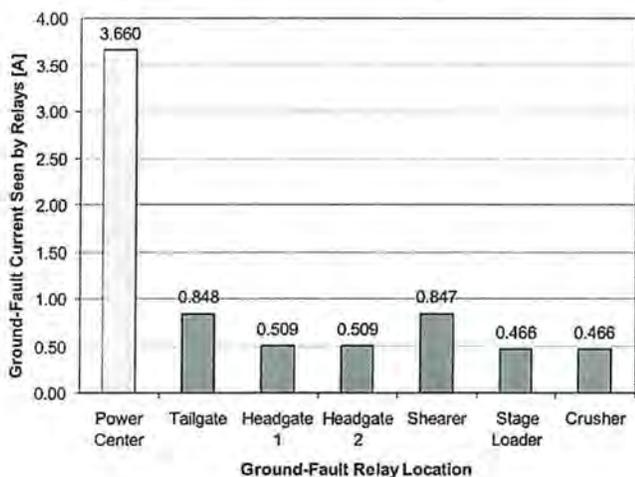
Fig. 12. Currents sensed by ground-fault relays with a bolted line-to-ground fault at the output of the power center for a 4160-V system.

tailgate are more susceptible to false tripping because of greater cable lengths, which result in more capacitance. Since the relay in the power center would have a time delay for coordination purposes, the shearer and tailgate circuits would trip first, followed by the power-center circuit. Given the location of the fault, only tripping the circuit breaker in the power center would clear the fault. Therefore, trip flags would be displayed at three different locations.

The problem becomes even more pronounced with the 4160-V system. Fig. 12 shows that the power center's ground-fault relay would sense 3.66 A with a ground fault at the output terminals of the power center. Fig. 12 also shows that ground-fault relays for all the outgoing motor circuits would sense currents in excess of their 0.125-A pickup settings. As a result, trip flags would be displayed at all locations.

The problems with relay selectivity could be eliminated by increasing the ground-fault-relay trip setting for the outgoing circuits in the motor starting unit. If the maximum value were increased from 0.125 A to 1.5 A, relay sensitivity would be maintained without compromising relay selectivity. The 1.5-A value

corresponds with 23% of the maximum neutral grounding-resistor current for the 2400-V system and 40% for the 4160-V system. The value is also 177% of the highest spurious ground-fault current sensed by the tailgate relay in the 4160-V system.

III. CONCLUSION

The high-voltage longwall regulations in 30 CFR went into effect in March 2002. In these regulations, MSHA increased the maximum limit of the ground-fault current through the neutral grounding resistor from 1.0 to 6.5 A for 2400-V systems and from 0.5 to 3.75 A for 4160-V systems. These increases now allow high-voltage longwalls to operate within the definition of high-resistance grounding. In other words, the charging current due to system capacitance will not exceed the current through the neutral grounding resistor during a ground fault. Results of computer simulations are summarized in curves that define the limits of the grounding-resistor current for 2400- and 4160-V high-resistance grounded systems. Curves are also presented that illustrate the effects of the neutral grounding-resistor current on potential overvoltages during a ground fault. The simulations show that resonant overvoltages can be adequately controlled by using ground-fault resistor-current limits of 6.5 and 3.75 A for the 2400- and 4160-V systems, respectively.

The high-voltage longwall regulations require the shearer and motor circuits to have instantaneous ground-fault protection set at not more than 0.125 A. Computer simulations show that relay selectivity is lost at this low value due to the high system capacitance from the shielded cables. The simulations verify that a ground-fault in one circuit could produce spurious tripping in other circuits because of the large capacitive-charging currents that return to the power-center transformer through the inherent system capacitance of all online circuits. The simulations also show that these selectivity problems could be avoided if the pickup setting were increased to 1.5 A. This should enhance the safety as well as the functionality of the system, although additional analyses need to be performed before a definite recommendation can be provided.

REFERENCES

[1] M. Sprouls, "Longwall census '84," Coal Age, pp. 47–58, Aug. 1984.
[2] ——, "Longwall census '85," Coal Age, pp. 50–65, Aug. 1985.
[3] ——, "Longwall census '86," Coal Age, pp. 48–57, Aug. 1986.
[4] ——, "Longwall census '87," Coal Age, pp. 44–53, Aug. 1987.
[5] ——, "Longwall census '88," Coal, pp. 68–77, Dec. 1988.
[6] P. Merritt, "Longwall census '89," Coal, pp. 34–43, Feb. 1989.
[7] ——, "Longwall census '90," Coal, pp. 38–47, Feb. 1990.
[8] ——, "Longwall census '91," Coal, pp. 42–49, Feb. 1991.
[9] ——, "Longwall census '92," Coal, pp. 28–35, Feb. 1992.
[10] ——, "Longwall census '93," Coal, pp. 28–35, Feb. 1993.
[11] ——, "Longwall census '94," Coal, pp. 28–35, Feb. 1994.
[12] ——, "Longwall census '95," Coal, pp. 32–39, Feb. 1995.
[13] ——, "Longwall census '96," Coal, pp. 34–39, Feb. 1996.
[14] S. Fiscor, "Longwall census '97," Coal Age, pp. 28–33, Feb. 1997.
[15] ——, "Longwall census '98," Coal Age, pp. 24–27, Feb. 1998.
[16] ——, "Longwall census '99," Coal Age, pp. 32–35, Feb. 1999.
[17] ——, "Longwall census '00," Coal Age, pp. 34–36, Feb. 2000.
[18] ——, "Longwall census '01," Coal Age, pp. 30–34, Feb. 2001.
[19] ——, "Longwall census '02," Coal Age, pp. 30–32, Feb. 2002.
[20] ——, "Longwall census '03," Coal Age, pp. 28–30, Feb. 2003.
[21] C. M. Boring and K. J. Porter, "Criteria for approval of mining equipment incorporating on-board switching of high-voltage circuits," in Proc. Ninth WVU Int. Mining Electrotechnology Conf., July 1988, pp. 267–274.

[22] L. A. Morley, T. Novak, and I. Davidson, "The application of 2400-V to longwall face equipment," *IEEE Trans. Ind. Applicat.*, vol. 26, pp. 886–892, Sept./Oct. 1990.

[23] T. Novak and K. Martin, "The application of 4160-V to longwall face equipment," *IEEE Trans. Ind. Applicat.*, vol. 32, pp. 471–479, Mar./Apr. 1996.

[24] T. Novak and J. L. Kohler, "Technological innovations in deep coal mine power systems," *IEEE Trans. Ind. Applicat.*, vol. 34, pp. 196–203, Jan./Feb. 1998.

[25] T. Novak, "Analysis of very-high resistance grounding in high-voltage longwall power systems," *IEEE Trans. Ind. Applicat.*, vol. 37, pp. 104–111, Jan./Feb. 2001.

[26] ——, "The effects of very-high resistance grounding on the selectivity of ground-fault relaying in high voltage longwall power systems," *IEEE Trans. Ind. Applicat.*, vol. 37, pp. 398–406, Mar./Apr. 2001.

[27] *Mining Cable Engineering Handbook*, General Cable., Highland Heights, KY, 1977, p. 69.

[28] M. Fuller, AmerCable, private communication, May 1998.

[29] B. Bridger Jr., "High-resistance grounding," *IEEE Trans. Ind. Applicat.*, vol. 19, pp. 15–21, Jan./Feb. 1983.

[30] J. R. Dunki-Jacobs Jr., "The reality of high-resistance grounding," *IEEE Trans. Ind. Applicat.*, vol. 13, pp. 469–475, Sept./Oct. 1977.

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