High-Voltage Longwall Database

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Abstract—A database was designed to accumulate the relevant information for all existing high-voltage longwall systems. This information was obtained from the Proposed Decision and Order documents issued by the Mine Safety and Health Administration (MSHA). Additional sources of information were obtained from MSHA approval documents and one-line diagrams of all active high-voltage longwalls. The data collected from these documents was incorporated into the design of a database that reflects the electrical information from each high-voltage longwall system.

I. INTRODUCTION

During the past several years, high-voltage (over 1,000 volts) longwall systems have become increasingly popular with underground coal mining operations. There are a number of reasons for this popularity. Utilizing a higher voltage reduces the amount of current necessary to provide the same power at the motor as compared to utilizing a lower voltage. In most cases, this allows for fewer, smaller cables to be used to feed the motors for the same horsepower. Smaller cables are much lighter and easier to handle than the large cables needed for the high current requirements of medium-voltage (950 volts) longwall systems. Another benefit of reduced current is the reduction in the I^2R losses dissipated by the cables. Other advantages include the elimination of the voltage regulation and torque reduction problems associated with the lower voltage longwall systems.[1]

There are a few disadvantages to utilizing a high-voltage system. These include the increase in the thickness of insulation needed on the cables and the inherent hazards associated with improper handling of the high-voltage cables. Higher voltage motors have increased windings and are typically more expensive than lower voltage motors of the same relative horsepower. However, because of the reduction in voltage regulation, the elimination of the start-up torque problem, and the increased efficiency, many coal operators are choosing to go the route of the high-voltage longwall system.

The purpose of this paper is to present the data from a selected anonymous high-voltage longwall system. Descriptions of several of the entries will be provided when needed for clarity.

II. DATABASE

There were several sources of information necessary to accumulate the data incorporated into the Electrical Database. These sources include the documents issued by MSHA during the petition for modification process, approval documentation provided by MSHA's Approval and Certification Center, and one-line diagrams of high-voltage longwall systems. Power system parameters including cable and transformer data were entered into a computerized analysis package to provide the database with short circuit calculations of each of the longwall systems.

The Proposed Decision and Order (PDO) documents are issued by MSHA in response to a request for a modification to an existing federal safety regulation. Section 101(c) of the Federal Coal Mine and Safety Act of 1977, 30 U.S.C., sec. 811(c), allows for mine operators or miners representatives to petition the Secretary of Labor to modify a safety standard. If the petition is granted, MSHA will detail specific requirements the petitioner must follow in a Decision and Order.

Mine operators or machine manufacturers must also submit specifications pertaining to high-voltage longwalls to MSHA's Approval & Certification Center for approval. Approval consist of a review of the equipment drawings and a field inspection of the installed longwall prior to operation.

These documents in conjunction with one-line diagrams obtained from MSHA inspection personnel provide the information for the database.

Table 1 displays the information in the same manner as it is presented in the database software package. The data displayed in this table is from an existing high-voltage longwall system. The mine name and other specific information has not been included in order to protect the identity of the mining company. Following the table is a list of the database fields used and their significance in the database.

"Mining Company", "Mine Name(s)", and "ID Number(s)" are self explanatory and are used mainly to search the database for information when one of these three fields are known.

The "Date" field provides the researcher of the database with the date of the Proposed Decision and Order of the modification petition submitted by the mining company.

The "Section Power Center" provides the information commonly found on the transformer nameplate such as "Input Voltage" and other parameters identified as "#1" or "#2" for single or dual winding transformers. These are "kVA", "Output Voltage", and "Percent Impedance". The minimum calculated short-circuit fault current ("Calc. SC") the main circuit interrupting device will be exposed to, along with the main circuit interrupting device current ("CID Setting"), and time settings ("CID Delay") are also included.

The remainder of the Electric Database is broken into sections that are identified by the motors of the high-voltage longwall system. Each section contains the same fields (e.g. - "Motor Voltage", "Motor HP", etc.). It should be noted at this point that the table shown above is generic in design. Every high-voltage longwall operation does not necessarily have two stage loaders or two head-face conveyor motors. As mentioned earlier, this table represents the way information is entered into the database and not necessarily the standard set-up for high-voltage longwall mining.

The "Motor Voltage" and "Motor HP" (horsepower) all provide information relative to the respective motor.

The "Cable Size" and "Cable Length" fields provide the information required for the calculation of the short- circuit current available at the end of the cable. This value is displayed in the field "Calc. SC Current".

The "CID Location" (circuit interrupting device location) provides the location of the primary circuit breaking device for each respective motor. This location is determined from either the approval documentation or one-line diagrams provided by the mine operator and/or MSHA electrical inspector.

The "CID Setting" states the actual or maximum allowable circuit interrupting device setting for each motor in the longwall system. This value is determined during the approval process by taking into account the fault current available at the end of each high-voltage cable and the motor starting characteristics, or from the approval documentation.

The "Disc. Location" gives the location of the motor's primary means of disconnect from the incoming power circuit. The "Starter Location" provides the location of the high-voltage motor starter.

III. RESULTS

This section will provide the ranges and averages of the parameters recorded in this database. The information from the section power center to each respective motor in the longwall system will be summarized below. The data displayed in this section is taken from the 30 high-voltage longwall systems that were surveyed for the database at the time this paper was written. All calculated short-circuit fault currents shown below are based on line-to-line faults.

A. Section Power Centers

The incoming voltage to the section power center ranged from 7.2 kV to 12.47 kV. In 18 out of the 30 systems, the input voltage was 7.2 kV.

Average power center size was 2,667 kVA for the high-voltage secondary. These ratings ranged from a low of 1,000 kVA to the largest being 4,000 kVA.

The most common utilization voltage found was 2,400 volts. The trend for newer systems is toward 4,160 volt systems. The majority of secondary utilization voltages were either, one high-voltage (67%), a combination of high- and medium-voltages (30%), or in one case, a 2,400 and 4,160 volt system (3%).

Transformer impedances varied from a low value of 2.9 percent to 7.0 percent. The average value was 4.59 percent.

The main circuit interrupting devices were usually located in the transformer secondary. Current settings varied from 1,200 amperes to 2,500 amperes. The most prevalent setting (46%) was 2,500 amperes. A setting of 2,000 amperes was found to be the most commonly used (29%). Main circuit interrupting device time delays varied from instantaneous to a maximum delay of 1.0 second. The most common setting (52%) was 0.10 seconds.

Several of the longwall systems had the motor controllers located inside the section power center. Most of the systems, however, had the high-voltage motor controllers located external to the power center. For these systems, the cables that fed the controllers ranged from 100 feet to 1,000 feet with an average length of 896 feet. The cable sizes ranged from #4/0 to 500 MCM. The most commonly used cable size was 500 MCM.

Calculated line-to-line short-circuit current at the end of the circuits protected by the main circuit interrupting device range from 1,938 amperes to 9,027 amperes with an average value of 4,074 amperes.

B. Stage Loaders

The voltages for the stage loader motors ranged from 950 volts to 4,160 volts with the mode (most often used) voltage being 2,400 volts (29 out of 35 researched). The horsepower ratings for these motors ranged from 100 to 350 horsepower with the mode being 200 horsepower (19 out of 35). Most of the stage loader motors were connected to the motor controllers via a size 2/0 cable; however, the range of cable sizes varied from #4 to #4/0 cable. The length of these cables ranged from 50 feet to 1,150 feet with an average cable length of 164 feet. The short-circuit currents available at the end of each of these cables ranged from 2,515 amperes to 8,693 amperes with the average being 4,238 amperes. Based on the design of the system and the available fault currents, the circuit interrupting device settings varied from 352 amperes to 2,500 amperes with an average setting of 1,050 amperes.

C. Crushers

The majority of high-voltage longwall systems used only one crusher in their design. The voltages for the crusher motors were the same as the voltages for the stage loader motors. The horsepower ratings for the crusher motors were slightly different than the horsepower ratings for the stage loader motors. These motors ranged from 150 to 350 horsepower with the mode being 150 horsepower (12 out of 29). A size #2/0 cable was the most commonly used cable (21 out of 27) with sizes ranging from #4 to #4/0. Cable lengths ranged from 10 to 1,150 feet with an average of 147 feet. Available short-circuit currents varied from 2,515 to 8,859 amperes with an average line-to-line short-circuit current of 4,274 amperes. The average setting of circuit interrupting devices for crusher motor circuits was 1,025 amperes while the settings ranged from 352 amperes to 2,500 amperes.

D. Face Conveyor Motors

Many of the high-voltage longwall systems required the utilization of two head-face conveyor motors and only one tail-face conveyor motor. The voltage rating of the conveyor motors ranged from 2,400 Volts to 4,160 Volts with a mode voltage of 2,400 Volts (46 out of 60). The horsepower ratings for the conveyor motors were consistently greater than the horsepower ratings of the other motors. They ranged from 300 horsepower to 640 horsepower with a mode rating of 500 horsepower (19 out of 60). Cable sizes were similar to that of the other motors with the most commonly used cable size of #2/0. The cables used for the conveyor motors ranged in size from #4 to #4/0. Cable lengths varied from 50 feet to 2,000 feet. Cables extending to the tail-face conveyor motors were longer because of the width of the longwall panels. This resulted in lower short-circuit current values available at the end of the tail-face conveyor motor's cables. The average cable length for a head-face conveyor motor cable was 327 feet; 1,200 feet was the average length for a tail-face conveyor motor cable. Available short-circuit currents varied widely because of the different cable sizes and lengths. The available short-circuit currents for the head-face conveyor motor cables ranged from 1,811 to 8,775 amperes and for the tail-face conveyor motor cables from 1,475 to 6,066 amperes. The average short-circuit currents available at the end of the cables was 3,842 and 3,316 amperes for the head- and tail-face conveyor motors, respectively. The circuit interrupting device settings for these motors ranged from 400 to 2,500 amperes with an average setting of 1,550 amperes.

E. Shearers

The voltage utilized for the shearer motors ranged from 950 to 4,160 volts with the most commonly used voltage being 2,400 volts (78%). The horsepower ratings varied widely from 370 horsepower to 1,480 horsepower with the average being 920 horsepower. The most common size cable used was a #4/0 cable; the high-voltage cables ranged from #1 to #4/0. The length of these cables ranged from 500 feet to 1,800 feet with an average length of 1,035 feet. Available short-circuit currents ranged from 2,132 amperes to 6,066 amperes with an average of 3,316 amperes. The settings of the circuit interrupting devices ranged from 800 amperes to 2,500 amperes with the average being 1,806 amperes.

IV. CONCLUSIONS

An analysis of the electrical database shows a trend towards the use of larger section power centers, longer trailing cables, higher voltage utilization equipment, and larger horsepower motors. This gives mine operators the option of varying the panel length and width to obtain a greater efficiency. Figure 1 shows the most common high-voltage longwall systems.

V. REFERENCE

[1] L. A. Morley, T. Novak, and I. Davidson, "The Application of 2400 V to Longwall Face Equipment," IEEE Transactions on Industry Applications, September/October 1990, pp. 886-892.

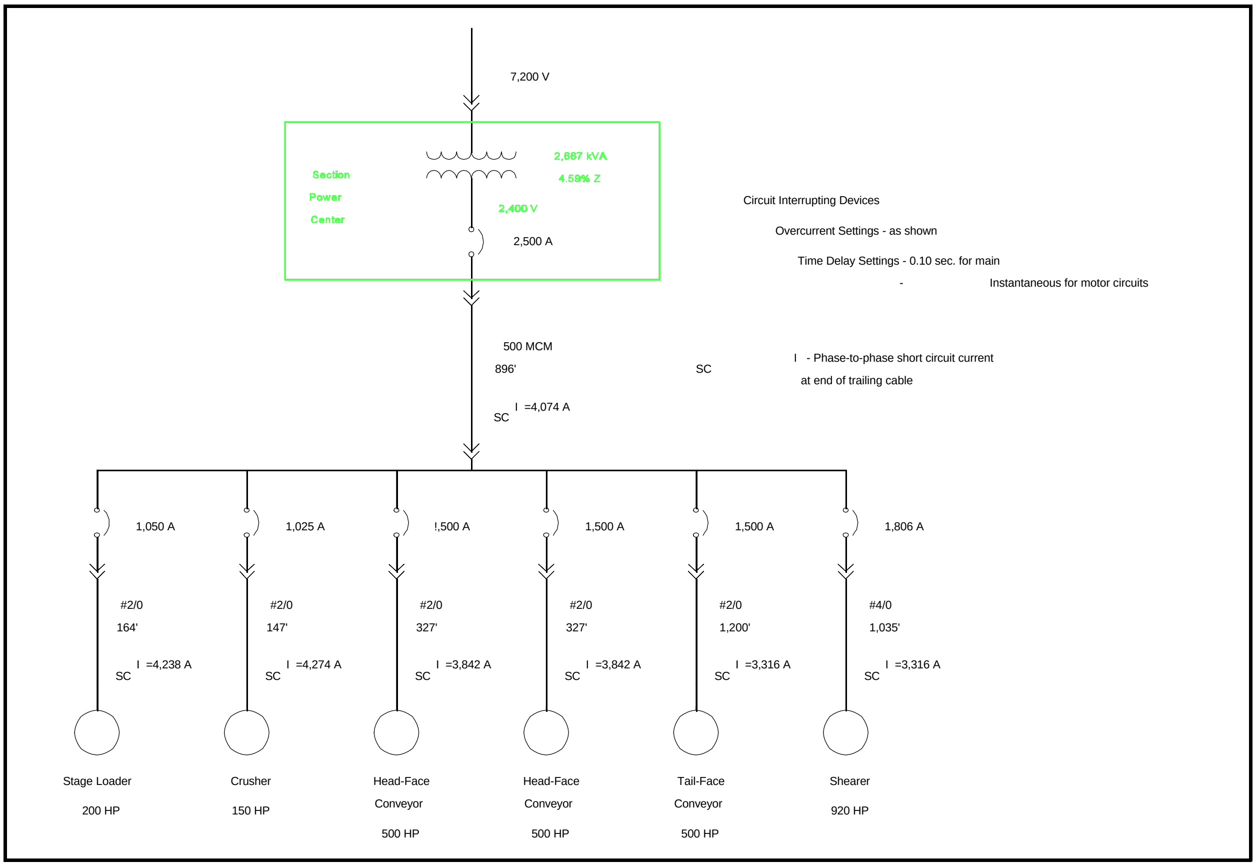

Figure 1. Most Common High-Voltage Longwall System

TABLE 1

MINING COMPANY:	XXXXXXXXXXXXXXXXXXXX
MINE NAME:	XXXXXXXXXXXXXXXXXXXX
ID NUMBER:	XXXXXXXXXXXXXXXXXXXX
DATE:	XXXXXXXXXXXXXXXXXXXX

SECTION POWER CENTER

kVA #1:	4,000
kVA #2:	1,000
INPUT VOLTAGE:	12,470 Volts
OUTPUT VOLTAGE #1:	2,400 Volts
OUTPUT VOLTAGE #2:	600 Volts
CABLE SIZE:	500 MCM
CABLE LENGTH:	995 Feet
PERCENT Z #1:	3.65
PERCENT Z #2:	2.60
CALC. S.C. #1:	9,027 amperes
CID SETTING #1:	2,500 amperes
CID DELAY #1:	0.25 second
CALC. S.C. #2:	
CID SETTING #2:	
CID DELAY #2:	

STAGE LOADER NO. 1

MOTOR VOLTAGE:	2,400 Volts
MOTOR HP:	300 HP
CABLE SIZE:	4/0
CABLE LENGTH:	100 feet
CALC. SC CURRENT:	8,693 amperes
CID LOCATION:	Motor starter enclosure
CID SETTING:	682 amperes
DISCON. LOCATION:	Motor starter enclosure
STARTER LOCATION:	Motor starter enclosure

STAGE LOADER NO. 2

MOTOR VOLTAGE:	2,400 Volts
MOTOR HP:	300 HP
CABLE SIZE:	4/0
CABLE LENGTH:	100 feet
CALC. SC CURRENT:	8,693 amperes
CID LOCATION:	Motor starter enclosure
CID SETTING:	682 amperes
DISCON. LOCATION:	Motor starter enclosure
STARTER LOCATION:	Motor starter enclosure

CRUSHER NO. 1

MOTOR VOLTAGE:	2,400 Volts
MOTOR HP:	300 HP
CABLE SIZE:	4/0
CABLE LENGTH:	50 feet
CALC. SC CURRENT:	8,859 amperes
CID LOCATION:	Motor starter enclosure
CID SETTING:	682 amperes
DISCON. LOCATION:	Motor starter enclosure
STARTER LOCATION:	Motor starter enclosure

CRUSHER NO. 2

MOTOR VOLTAGE:	
MOTOR HP:	
CABLE SIZE:	
CABLE LENGTH:	
CALC. SC CURRENT:	
CID LOCATION:	
CID SETTING:	
DISCON. LOCATION:	
STARTER LOCATION:	

HEAD FACE CONVEYOR NO. 1

MOTOR VOLTAGE:	2,400 Volts
MOTOR HP:	640 HP
CABLE SIZE:	4/0
CABLE LENGTH:	75 feet
CALC. SC CURRENT:	8,775 amperes
CID LOCATION:	Motor starter enclosure
CID SETTING:	1,225 amperes
DISCON. LOCATION:	Motor starter enclosure
STARTER LOCATION:	Motor starter enclosure

HEAD FACE CONVEYOR NO. 2

MOTOR VOLTAGE:	2,400 Volts
MOTOR HP:	640 HP
CABLE SIZE:	4/0
CABLE LENGTH:	75 feet
CALC. SC CURRENT:	8,775 amperes
CID LOCATION:	Motor starter enclosure
CID SETTING:	1,225 amperes
DISCON. LOCATION:	Motor starter enclosure
STARTER LOCATION:	Motor starter enclosure

TAIL FACE CONVEYOR NO. 1

MOTOR VOLTAGE:	2,400 Volts
MOTOR HP:	640 HP
CABLE SIZE:	4/0
CABLE LENGTH:	1,100 feet
CALC. SC CURRENT:	6,066 amperes
CID LOCATION:	Motor starter enclosure
CID SETTING:	1,225 amperes
DISCON. LOCATION:	Motor starter enclosure
STARTER LOCATION:	Motor starter enclosure

TAIL FACE CONVEYOR NO. 2

MOTOR VOLTAGE:	
MOTOR HP:	
CABLE SIZE:	
CABLE LENGTH:	
CALC. SC CURRENT:	
CID LOCATION:	
CID SETTING:	
DISCON. LOCATION:	
STARTER LOCATION:	

SHEARER MOTOR

MOTOR VOLTAGE:	2,400 Volts
MOTOR HP:	1,480 HP
CABLE SIZE:	4/0
CABLE LENGTH:	1,100 feet
CALC. SC CURRENT:	6,066 amperes
CID LOCATION:	Motor starter enclosure
CID SETTING:	1,472 amperes
DISCON. LOCATION:	
STARTER LOCATION:	Motor starter enclosure