Paper No. 208

ISMS 2016

Electrical equipment certification in Canadian underground coal mines – problem solved?

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ABSTRACT
Certification of electrical equipment for underground coal mines in Canada is problematic. EX protected electrical distribution equipment to Group 1 standards is not manufactured in Canada, and even if it were, there is no facility in Canada that is accredited to certify it. The Canadian Federal laboratories previously tasked with the job are now closed. Provincial regulations require certification by either a now-defunct facility or by the US authorities (MSHA). Unfortunately the underground coal legislation in the US is significantly at odds with Canadian Provincial legislation and equipment approval requirements, which presents problems with equipment certified there.
Although the underground coal mining industry in Canada is small, the western Provinces are blessed with substantial resources of high quality steel-making coal, much of which can only be accessed by underground mines. There are perhaps half a dozen large underground projects awaiting a price revival in Alberta and British Columbia, and it was the authors' experience at one of these projects that led to this paper.
The project in question was owned by a Chinese company that wanted to use Chinese electrical distribution equipment certified in China to IEC equivalent standards. The process of convincing the Provincial regulators that the Chinese equipment was safer than the equipment that would be allowed under Canadian standards was arduous, but ultimately successful. The next step was to seek changes in the Canadian electrical standard applicable to mines so that the benefits could be felt across the country. This has recently also been accomplished.
This paper examines the problem through an important aspect of electrical safety in underground coal mines - protection against electric shock and arcing. It compares the requirements of the Canadian legislation, US, and UK legislation and IEC standards used by other countries.
It concludes that the levels of safety against shock and arcing afforded by IEC-certified multi-point systems can be orders of magnitude better than the single point systems mandated or traditionally used in Canada. Additionally, multi-point systems may be better suited to protect high voltage equipment beginning to be deployed in large open pits than the current Canadian protection standards. The recommendations arising for changes to Canadian standards await ratification, and the authors are hopeful that they will be adopted by Provincial regulators as soon as practicable.
KEYWORDS: ground fault protection, equipment certification, hazardous locations, electrical standards.

1. INTRODUCTION

The Canadian underground coal mining industry has a long history, although currently it is almost extinct. However, Nova Scotia and the western Provinces of Alberta and British Columbia still hold valuable resources of steel-making coal, much of which can only be accessed from underground. There are perhaps half a dozen large underground projects awaiting a price revival in Alberta and British Columbia, and it was the authors' experience at one of these projects that led to this paper.

The major underground mining Provinces, Nova Scotia, Alberta and British Columbia have developed their own safety legislation in response to their history of mining tragedies and the idiosyncrasies of their underground mines. These safety codes rely on underlying safety standards developed and updated as required by stakeholder committees struck by the Canadian Standards Association. The safety of electrical installations in mines, including underground coal mines, in Canada is governed by CAN/CSA M421-11 "Use of Electricity in Mines" (CSA, 2011).

M421 sets out the standards which electrical equipment must achieve and requires that equipment used in underground coal mines either be certified by a certification organization accredited by the Standards Council of Canada in accordance with the requirements of a CSA Standard (or another recognized document when an applicable CSA Standard does not exist) or it must meet the requirements of the authority having jurisdiction.

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Provincial regulators require that the certification be issued by the long extinct UK Ministry of Fuel and Power, the Canadian Explosive Atmospheres Research Laboratory, which no longer provides certification services, or MSHA in the USA.

Thus, certification of electrical equipment for underground coal mines in Canada is problematic. EX protected electrical distribution equipment to Group 1 standards is not manufactured in Canada, and even if it were, there is no facility in Canada that is accredited to certify it. The Canadian Federal laboratories previously tasked with the job are closed. Unfortunately the underground coal legislation in the US is significantly at odds with Canadian Provincial legislation and equipment approval requirements, which presents problems with equipment certified there.

2. BACKGROUND

An underground coal project in NE BC provided the initial impetus for a re-assessment of the Canadian standards and certification requirements. The Chinese owners wanted to import Chinese equipment to use in the mine. The equipment was certified in China to Explosion Protected IEC Group 1 Standards (gassy mines) by laboratories in China accredited under ISO/IEC Standard 17025.

Certification to IEC Group 1 (gassy mines) Standards can be achieved using most internationally recognized explosion protection technologies, for example: explosion-proof or flame-proof "d"; intrinsically Safe "i", or increased Safety "e", among others.

The electrical classification of underground coal mines internationally is varied. In some jurisdictions a zoning system is required and is defined, in general, to similar requirements of Section 18 of the CEC, although there can be differences dictated by the authority having jurisdiction; other provinces in Canada and other countries allow only equipment certified to Group 1 standards to be installed in underground coal mines. In 2004, Alberta allowed the application of the CEC zoning system to be applied in underground coal mines.

The Canadian Standards Association has adopted these technologies and applies them to their surface hazardous location (Group 2) certification requirements. The technical requirements of these categories are detailed in the CSA and IEC 60079 series of Standards.

There are significant differences between MSHA and other international "Explosion Protection" standards for Group 1 applications, although in general they achieve the same levels of safety; MSHA only recognize "explosion proof" and "intrinsically safe" technologies in underground coal mines, although they do legislate a form of "increased safety" and apply it to battery installations on "permissible" machines. The underground coal mine is divided into two areas or zones, namely "permissible" and "non-permissible". Equipment inbye of the last fresh air cross-cut is required to be certified to their EXP and I.S. standards while equipment outbye in the fresh air is generally to industrial standards.

The British Columbia Health, Safety and Reclamation Code for Mines (HSRC, 2008) only accept equipment certified for use in gassy mines by the Canadian Explosive Atmospheres Laboratories (NRCAN) and the Mines Safety and Health Administration in the United States (MSHA). Since NRCAN no longer certify electrical equipment for use in gassy mines, and EX protected electrical distribution equipment to Group 1 standards is not manufactured in Canada, and the underground coal legislation in the US is significantly different to Canadian provincial legislation and equipment approvals, it has proved necessary to review other international standards for equipment produced and imported from countries other than the US.

Notwithstanding the fact that the Chinese equipment had not been certified by authorities recognized by the Provincial regulators, there were also questions raised about the ground fault protection methods used on the equipment which were very different from those which have become commonplace in Canadian underground coal mines. This prompted a detailed review of the ground fault (earth leakage) protection systems incorporated into the switchgear and transformer assemblies to determine if it could be used under a variance to safety codes on the grounds of "equal or greater safety".

3. GROUND FAULT PROTECTION

Ground fault protection systems in underground coal mines have been developed to a far greater degree of safety than the rest of the mining industry due to the many hazards associated with mining in gassy atmospheres; the sophistication, sensitivity and speed of operation of the two systems discussed below are designed to eliminate the electric shock hazard produced by ground fault voltages completely and to limit ground fault energy levels to reduce the possibility of gas ignitions due to damage or mal-function of electrical equipment.

The two systems are:

1. Single point (SEL)
2. Multi-point (SEL)

Both systems have been used extensively in underground coal mines since the early 1960's and have proven to be reliable and effective in reducing electrical incidents; the systems are unique and cannot be interconnected or mixed in any way without affecting their safety levels and/or rendering the protection systems inoperative.

The review of IEC certified equipment from China recently installed in a BC underground coal mine shows significant differences of electrical protection technology when compared to Canadian requirements set out in the Canadian mining electrical standard (CSA M421-2011). While the Canadian requirements generally apply themselves to single point high resistance neutral grounding systems, specifically referenced to achieving limits to ground potential rise due to ground faults, the Chinese earth leakage protection systems are based on the principals of a multi-point grounding system, developed in the 1960's by the National Coal Board in the U.K. These systems achieve greater sensitivity and speed of operation than the requirements of M421, and thus have a greater degree of safety in gassy atmospheres where incendive sparking from damage to electrical equipment is a distinct hazard.

The single point and multi-point grounding protection systems are described below and compared to the requirements of the Canadian standard.

3.1 Single Point Systems

The single point system of protection has, over the past 40 years or so, been adopted in Canada in the coal mines in Nova Scotia, Alberta, and British Columbia, and uses UK manufactured FLP transformers and switchgear. Some of this equipment, with protection systems based on the earlier relay technology, is still in use at the Quinsam Mine in Campbell River, BC.

Figure 1 shows a protection unit for high-impedance single point earthing systems and incorporates an earthing or grounding impedance directly coupled to the transformer secondary star point. The original value of this impedance was set to limit fault current to 0.25 ampere with a "solid" earth fault. The systems imported into Canada were designed to operate with a 5 to 10 amp current limiting reactor connected to the star point of the FLP transformer. When an earth or ground fault occurs on the system, the flow of current to ground unbalances the three-phase system and the resulting unbalanced currents are detected by a core balance transformer, or zero sequence current transformer, causing the protection unit to trip.

Of note is the search circuit or look ahead circuit, which prevents closure onto an existing fault after the unit has tripped.

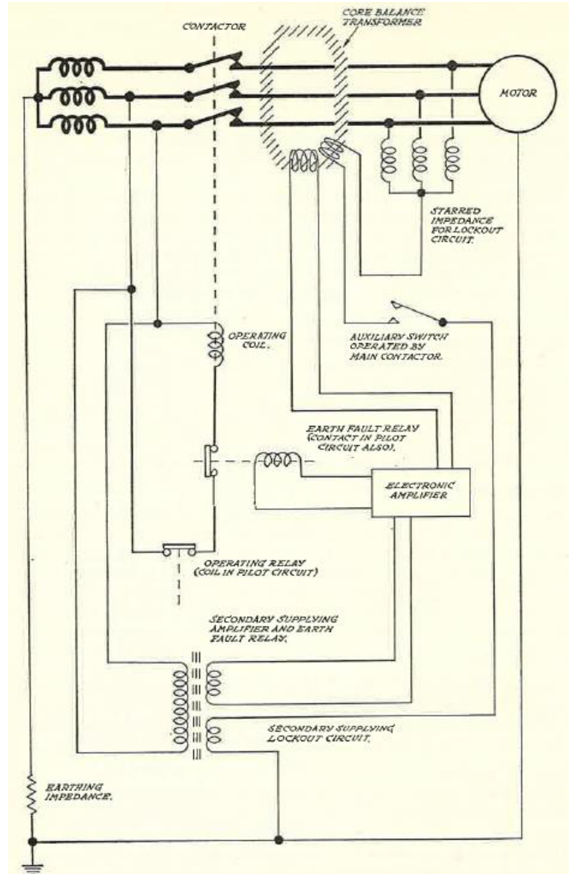

Figure 1: Typical Single Point Earthing System (after NCB, 1976).

3.2 Multi-Point Systems

In multi-point systems the transformer neutral is left "free" and is not directly grounded (Figure 2); each transformer secondary and each section switch and motor control switch protection unit is fitted with a starred impedance connected across the power conductors and the star point or artificial neutral is connected to ground through a further high impedance.

When a ground fault occurs on the system, return paths for the fault current are provided by the ground conductors on the system and the derived neutral impedance of each protection unit, and there are as many ground return paths as there are units on each system. The fault currents are limited to a level that cannot produce heating and any incendive sparking is confined to the area of the fault, and reduces the possibility of a shower of sparks. The ground fault current will pass through every detection circuit in each unit in operation on the system at the time the fault occurs; it can therefore be expected that every unit will trip, although this does not always occur in practice. The unit feeding the ground fault is prevented from being re-energized onto the fault by a lock-out or look ahead circuit which cannot be reset if the fault still exists; other units operating on the system which may also have tripped can be restarted without any reset.

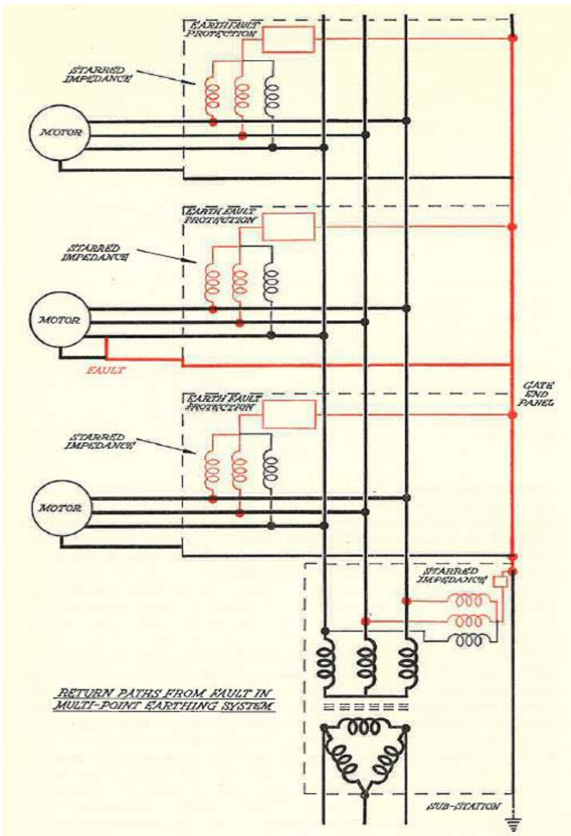

Figure 2: Typical Multi-Point Earthing System (after NCB, 1976).

The Chinese IEC certified units proposed for use in Canada utilize a starred impedance and signal amplifying system that is used to trip the primary switch feeding the transformer. They also include an earth leakage test facility built into the system which, when operated, connects a phase to ground through a 1K ohm resistor and facilitates regular testing of the protection system.

Both systems meet the standard. Given the superiority of the multi-point system and the lack of facilities to certify any overseas systems in Canada, a strong case is made to expand the scope of the Canadian standards so that Canada is not left behind.

4. SYSTEM COMPARISON

The CAN/CSA M421-11 standard requires that ground fault protection, where required, is provided through a neutral grounding device that limits ground fault voltage to 100 V or less and is de-energised in less than 1 s if the ground fault current exceeds 20% of the prospective ground fault current. It should be noted that the standard refers to a “device” not a resistor, although another section of the Standard requires a “neutral resistance”.

An interpretation of certification requirements was that “neutral resistance” had to be a resistor lead to the initial rejection of the Chinese equipment proposed for use underground.

5. NEXT STEPS

Presented with two problems, namely an unfamiliar earth fault protection system and equipment that had not been certified by a listed agency, a program was developed to provide a means of allowing the BC Chief Inspector to allow the equipment to be used on the grounds of “equal or greater safety” under a process known as a “variance” to the written code.

This process involved visits to China by company consultants and inspectors working for the Chief Inspector. Meetings were held with equipment manufacturers, testing facilities, underground mines and regulators. The certification and testing standards were thoroughly reviewed and compared to the appropriate IEC standards.

During the analysis of the information, the CANMET Report “Equipment Approval Guide for Underground Coal Mining Equipment” (CERL Report 2009-19 (TR) was used to develop an approval process for the Chinese equipment that would ensure that it met the high levels of safety enshrined in the Canadian standards.

This guide specifically states that making a direct point-by-point comparison of the two certification schemes (IEC & MSHA) for explosion-proof protection is not easily accomplished. Each is considered an effective system, despite being developed independently. Although the approaches are dissimilar, both are technically valid and have a history of successful application, although the differences in approach to explosion-proof and flameproof standards, as well as the single and multi-point protection systems dictate that the two systems cannot be mixed.

Establishing that the approaches were technically valid was a major step in obtaining the variance. Perhaps more compelling was the argument that although M421 limits ground fault voltages in underground coal mines to 50 V with a maximum tripping time of 1 second when fault current exceeds 20% of the prospective ground fault current, the Chinese system, which is performance tested to the specifications of Chinese Standard MT/T 661 – 1997 limits ground fault voltage to less than 1 volt on systems up to 1140 V, effectively eliminating the shock hazard, and tripping times of less than 100 ms.

The 10.5 KV systems are limited to less than 25 V ground fault voltage, currents are limited to a maximum of 6 amps, with tripping times of less than 100 ms.

The insulation (look ahead) monitoring system, which is designed to prevent closure onto an existing ground fault is set to trip at 20 k-ohms, and not allow reset and restoration of power until the insulation resistance has been raised to 40 k-ohms.

After a period of two years and much discussion, a variance to use the equipment in British Columbia was obtained.

6. CONCLUSIONS

A comparison of the single and multi-point systems discussed above does not favor one over the other; they are both proven technologies and have, for many years, operated throughout the international mining industries.

The single point system has one fault limiting device inserted directly into the supply transformer star point, the failure of which would render the protection system inoperable which is why neutral grounding resistors are required to be continuously monitored. However, the multi-point system has a number of derived neutral grounding devices and ground paths in the system and thus has a degree of protection against failure of one protection unit.

The objectives of the ground fault protection requirements in CSA Standard M421-11 are to limit touch potentials (ground fault voltages) to tolerable levels (see Table 52 CEC) and to trip the supply in less than 1 second. Section 7.9.6 of M421 requires that ground fault voltage be limited to 50 V in underground coal mines. There is no consideration given to limiting the energy in ground faults to levels that reduce the likelihood of incendive sparking.

As the use of electricity in surface and underground mines expands and the size of distribution transformers is increased, it is becoming more difficult to achieve the GPR limits on single point high resistance grounded systems because of the increased magnetizing currents on the system which dictate the limits of prospective ground fault current. On some 72K V distribution systems to mining moveable equipment in Canada, due to the size of the supply transformers, up to 150A is the minimum that ground fault current can be limited to in order to achieve the 20% ratio between prospective current and trip settings.

Other difficulties are being experienced on installations where the resistance of the return ground path, due to the distances involved, cannot be maintained to achieve the required GPR limits. The Potash mines in Saskatchewan are experiencing this kind of challenge and the "Petersen Coil" based system is being investigated for possible use in mines. The theory behind this resonant system is based on a tuned circuit and is widely used in Europe for HV transmission systems, where the source star point is grounded through a reactor sized to three times the system per phase capacitance. When there is a ground fault, the reactor tunes with the capacitance and the fault current is very small, therefore the GPR is small. For mining, ground conductor monitoring can still be done, as the cables are the same. Apparently these systems are used in mines in Europe and a few in the USA and are certainly worthy of further investigation.

The Chinese equipment installed in BC is not subject to the limits imposed by supply transformer size and maintains resulting touch potentials from a ground fault to less than 1 volt on the systems up to 1140 V thereby eliminating this electric shock hazard completely, and significantly reducing the potential for gas ignitions from electric arcs or sparks in the area of the fault. Tests conducted at the manufacturers in China on the 1140 V systems demonstrated tripping levels at less than 30 milli-amps in less than 100 ms. Ground fault limiting devices, which can include resistors, reactors, transformers, capacitors, and other components sometimes used in combination, are tuned to the cable range they operate on and can be adjusted to suit changes in the distribution system to achieve the most sensitive tripping levels.

7. RECOMMENDATIONS

The requirements for grounding systems in underground coal mines should be directed at limiting fault current rather than ground potential rise, where even at the present 50 V limit, current levels of 25 amps and higher can meet the requirements of the Canadian standard.

The Canadian standard would benefit from wording similar to the UK Approved Code of Practice, which stipulates that for power systems where there is a high risk of fire, shock, or ignition of flammable gas, limitation of the maximum prospective leakage fault current should be practiced. The fault current and its duration should be limited to as low a value as is reasonably practicable to minimize the risk of shock or damage leading to incendive sparking or arcing.

In addition to this change, reference to "resistances" for ground fault protection should be replaced by references to "current limiting devices"

All alternating current systems in underground coal mines should be subject to a maximum allowable ground fault current depending on their location in the mine and subject to any Zoning or electrical classification requirements.

8. ACKNOWLEDGEMENT

The authors acknowledge the support of H.D. Mining International Ltd. of Vancouver BC who sponsored much of the review work described above.

The views expressed are those of the authors, and may not represent the views of their employers.

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