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Review of Grounding Practices on Power System in Indian Underground Coal Mines with Futuristic Projections

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***Abstract*—The grounding system requires for maintaining safety of operators and apparatus, and ensuring reliable working of the power network. The main objectives of grounding system are to provide a means to transfer electric current into the earth under normal faulty conditions without exceeding any working and equipment limits or badly affecting continuity of service and safety of any person in the vicinity of ground services. The grounding system is reducing the risk of danger of critical electric shock. In this paper an attempt has been made to identify the means of different grounding practices, keeping in mind the present as well as the futuristic projection of the Indian underground coal mines. It is probable that there may be radical transformations from present day grounding system to other system/systems compatible for future mining conditions. However, it is essential to get prepared for that inevitable situation to make underground coal mining safer and efficient.**

***Index Terms*— Grounding system, Electric shock, Safety, Faulty condition.**

I. INTRODUCTION

The connection to earth or ground which is referred to as mine grounding system is a vital part of any mine power distribution system [1]. The grounding system serves to protect operators and apparatus from the dangers with electrical equipment that is operating wrongly [2]. The single-phase earth fault is the most common fault in a coal mine power supply system and it may lead to fire breakout that consequently may cause loss of property, affect the normal operations of the mine and affect human safety. Such phenomenon has high potential for a disaster in an underground coal mine, specifically in the coal mines of higher degrees of gassiness, where in addition to the hazards as mentioned above due to the leakage of fault current, there may be an occurrence of the explosion of inflammable gasses (CH_4& another hydrocarbon) [3].

In underground coal mines in India there is a wide variation of the voltage limits depending upon the statuary demands, the machinery used and their configurations [4]. The concentration of a considerable number of machines and auxiliary equipment increase a probability of the accidental earthing mostly caused by a mechanical failure of the tailing cables isolation [5]. While the hazard associated with single phase earth fault is prevalent practically for all voltages and circuits, the dimension of single-phase earth faults increases proportionally with higher voltage systems.

Due to the sheer nature of mine environment and jobs related to mining activities, the power circuits and the

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equipment they serve are subjected to rough handling, overloading, falling rocks, dragging through surfaces, frequent cable joints, high moisture content in the ambience, dryness of the floor leading to failure for providing low resistance grounds. These problems associated specially for portable equipment and trailing cables.

With the present trend of coal mining in India, which focuses on the necessity for working deeper deposits, the situation is projected to be further degraded in consideration of the following factors:

i. High level of mechanization with high voltage system
ii. More difficult environment conditions in deeper underground mines, such as more ambient temperature of general body of air, higher strata temperature and strata pressure
iii. More difficulty in getting low resistance ground
iv. More potential for emission of inflammable gasses
v. More concentration of main and auxiliary equipment

Above all, these factors may further culminate into the higher risk potential of the electrical power distribution system. Thus, the grounding system in electrical power distribution is to be installed such that it will ensure the safety of apparatus and operators during the normal and faulty condition. For the safe operation the value of step and touch potential should not increase the tolerance value [6]. Further, the ground potential rise (GPR) should be kept low either by reducing the ground resistance or fault current value [7]. Moreover, the potential energy of fault current must be kept lower than 0.3mJ to prevent any explosion risk caused by inflammable gasses [8]. These problems can be resolved by implementing a good grounding system in the electrical power distribution system of underground coal mines. Therefore, in this paper a detailed study of various grounding practices on the electrical power system in Indian underground coal mines has been made which further helps in finding the futuristic projections of good grounding practices.

II. Purpose of Grounding Practices on Power SYSTEM IN Underground Mining

A good grounding system serves to protect operators and apparatus from the hazards associated with the electrical equipment that is operating under faulty condition. A pertinent grounding system performs four main functions in the power system which are discussed in the below sections.

Fist, the grounding system must provide as low as the minimum value of the ground potential rise (GPR) [7]. This is mainly due to the contact of the phase conductor with a machine frame during a ground fault condition. As a result of this, a current start flowing through the equipment which increased the potential of the equipment above ground potential by an amount equal to the voltage on the conductor. Now, if any operator touches the equipment from the ground the then his body potential can be elevated possibly to a lethal extent. The maximum potential experienced by an operator is the voltage drop along the ground conductors. Thus, the grounding system must provide a low resistance path for a fault current with a minimum voltage drop [9].

Second, the grounding system should limit the energy release from the equipment during the faulty conditions [10]. The heavy sparking or arcing may ignite nearby combustible material. Thus, the controlling of the energy release from equipment can minimise the probability of fire and equipment damage to a minimum extent.

Third, the grounding system should control the over voltage which may occur due to the various activities, such as accidental contact of equipment with a higher voltage system, from transient phenomena due to lighting strokes, autotransformer connections, switching surges and intermittent ground fault [10]. Due to overvoltage condition the power system equipment does not breakdown immediately, but it experienced overstressed which may weekend by the repeated action of overvoltage. This phenomenon leads to premature failures of power system equipment which may occur without any apparent reason. This problem may overcome by providing a path a path between neutral point and ground, which may reduce or possibly eliminate the source of transient overvoltage [11].

Fourth, the grounding system should isolate the faulty parts of a power system from the healthy parts by selective relaying of ground fault [7]. If a proper relaying system is not provided to the component of mine power system then nearby circuit breaker may bot trip and a small problem could escalate in to a large calamity. As a result, the power to half mine may go out because of poor relay coordination and much of time may lost to locate the tract the faulty spot. Thus, the relaying system must be arranged in such a manner that a sufficient amount of fault current can flow through the protective circuitry to enable it even at the lowest level of power distribution system.

III. EXISTING GROUNDING SYSTEMS

Over the past few decades several grounding techniques were purposed with their own advantages and disadvantages. These techniques are discussed in subsequently in the below sections.

IV. UNGROUNDED GROUNDING SYSTEM

The ungrounded system was probably the first to be used in underground mines power system because of its simplicity. In this grounding system there is no direct connection between neutral and ground. Therefore, the first ground fault on such system will have very little effect because there is no direct path for the fault current and its magnitude will be very small [12]. This very low fault current will result no flash hazard and equipment damage. The first fault is often very hard to locate because its negligible effect, so, there is no repair action is made until a second fault occurs which reduces the reliability of the power system equipment's. Since, the entire system is floating therefore no control of transient overvoltage which may cause due to the lighting strokes. However, a perfect ungrounded system never exists in practice, because any current carrying conductor may be coupled with the ground through numerous paths, such as distributed capacitance of the conductor wiring and through motor winding. Further, this distributed capacitance to ground enhanced the voltage level of power system equipment during the faulty condition. Thus, ungrounded grounding very rarely usage grounding system the mines power system. The schematic diagram of an ungrounded grounding system is shown in Figure 1 [1].

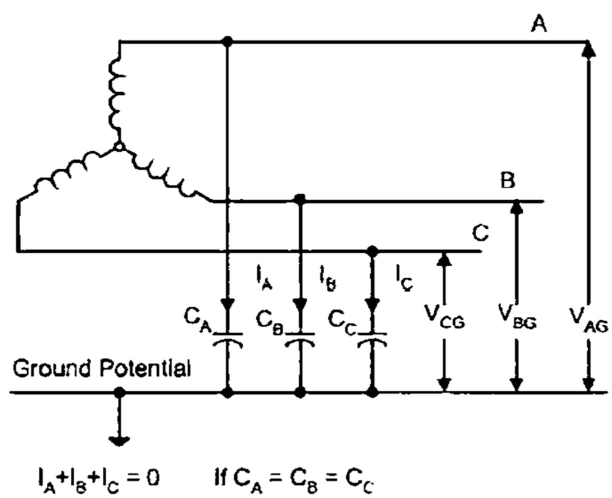

Figure 1. Schematic diagram of an ungrounded system

V. SOLIDLY GROUNDED SYSTEM

A power system is said to be solidly grounded when the neutral of a power system component are directly connected to a ground through a conductor of negligible resistance or reactance [13]. The first fault produces a sufficient neutral current flow, which may quickly sense by a protective circuitry, thereby a faulty portion can be removed from the healthy part of a power system. The schematic diagram of a solidly grounded system is presented in Figure 2 [1]. The solid grounding system provides a return path for a fault current but does not limit the flow of fault current (as there is no opposition to current flow). As a result, a large fault current can flow through the protective device which may explode protective enclosure, destroy equipment, and start fire. Hence this grounding is generally not preferred in explosive atmosphere.

VI. LOW-RESISTANCE GROUNDED SYSTEM

In order to limit the magnitude of earth fault current, it is a common practice to connect the neutral point of a 3-phase system to earth through a resistor. This resistor is called ground resistor and this technique is called Resistance Grounding. A low resistance grounding limits the line to ground fault current normally between 100A to 1000A as defined by IEEE standard 142-2007 (section 1.4.3.2). the fault current from 50A

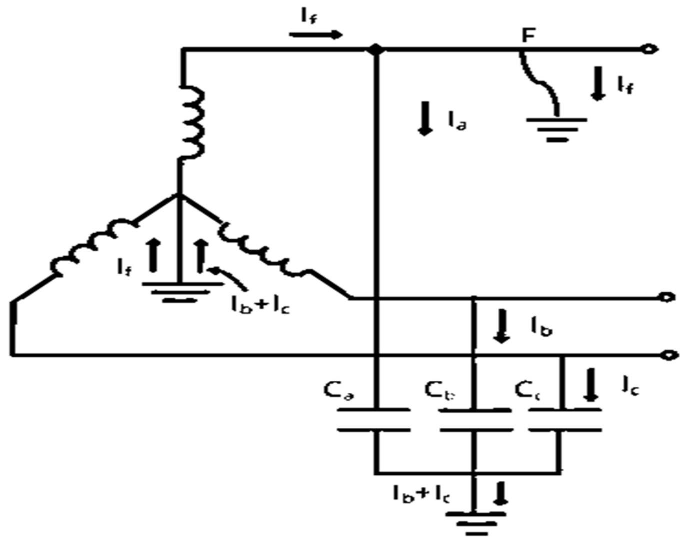

Figure 2. Solidly grounded system

to 600A [14], but are commonly about 400A. In this grounding system the transients are controlled by the ground connection and a simple fault current is available to activate the fault current. The possibility of flash hazard in this grounding system is not as serious as in solid grounded system. This grounding system may capable of reducing the arcing current or flash to some extent but not eliminate completely, which may damage the power system equipment. Thus, method can be modified by a high resistance grounding system. A schematic diagram of low resistance grounding is shown in Figure 3 [1].

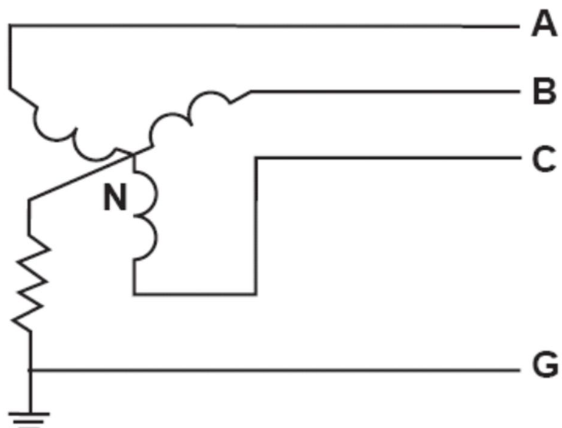

Figure 3. Low resistance grounded system

VII. HIGH-RESISTANCE GROUNDED SYSTEM

A high resistance grounding limits the line to ground fault current normally less than 10A as defined by IEEE standard 142-2007 (section 1.4.3.1). This grounding system completely reduce the high transient over voltages and limits the damage faulted equipment. The amount of fault current is also low enough to practically eliminate arcing and flash over dangers. Since, a low fault current flowing in this system so protective equipment must detect faults on the order of a few amperes such that a faulty part can be remove from the healthy part in a power system. However, in this grounding system, loads cannot be connected between line to neutral, since the grounding conductor not carry any load current. A typical high resistance grounding system is presented in Figure 4 [1].

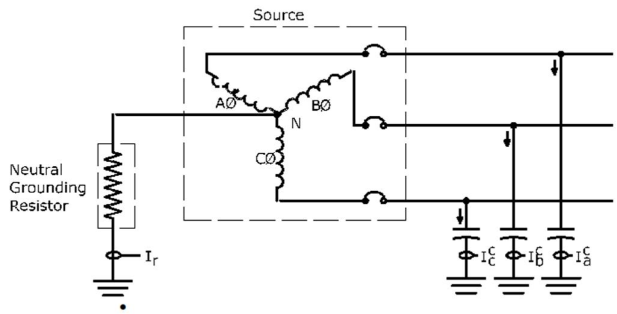

Figure 4 High resistance grounded system

VIII. Analysis of Grounding Practices

An ungrounded system is a simple and oldest practice of grounding of electrical equipment. In this type of grounding system, the nature and magnitude of fault current is very small which practically causing no flash hazard and equipment damage. But, the first fault in ungrounded system is very hard to locate since it has a negligible amount of fault current which reduces the reliability of the power system component at the time of repeated fault causing huge damage to the power system component. Also, in ungrounded system there is no provision to control the transient overvoltage which may cause due to the lighting & switching phenomena and the application of autotransformer. Therefore, this grounded system is rarely practiced in mine power system.

In solid grounding system a substantial amount of fault current flow through the solid grounding wire at the time of fault which enables the protective device such that it can isolate the faulty parts from the healthy one. Since, the solid grounding system allows a large fault current to flow through the protective device, therefore, a protective device component can be damaged even may become a source of ignition or flash hazards which leads to the fire in an underground mine. Therefore, this type of grounding is not recommended for the underground application.

The fault current can be substantially reduced in low resistance grounding when compared to a solid grounding system by means of low resistance grounding. Thus, the low resistance grounding is able to reduce the flash hazard problem, but not completely. Therefore, to reduce the chances of flash hazard completely a high resistance grounding system is gaining more importance in an underground mine power system application. In high resistance grounding system, the fault current can be reduced to a safer limit which will reduce the possibility of flash hazards or arcing completely from the underground mines power system applications, in fact it is cable of eliminating the arcing. The only probable drawback of the high resistance grounding system is that, since, the fault current is very small which may not sufficient to trigger/activate the protective devices for isolation of faulty part from the healthy part of mines power system.

IX. Conclusions

The proper and efficient grounding system is very much essential for the safe and reliable operation of the electrical power system components in the hazardous environment of underground coal mines. From the analysis of four prevailing grounding system, as discussed in this article, it is appeared that the high resistance grounding system has the highest potential to limit the fault current and energy release in case of any occurrence of fault. In the context of planning the futuristic mines with much higher load, higher voltage system and more difficult environmental condition in deep and gassy mines a high resistance grounding system would provide the safest condition for operation. However, it requires to be ensured that the limited fault current should be capable of triggering the protective circuit for isolation. The research for this purpose is imperative for establishing the relationship between load, voltage, energy released and earth fault current.

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