Smart Mobile Earthing Trolley (SET) to Operate Aluminium Smelter Potline with Fixed Null Point

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Abstract

Modern aluminium smelters are operated at high DC currents and potline voltages up to 2000 V. These pot lines are usually earthed at mid-point to bring the potential of the pot lines with respect to earth to a maximum of ± half of pot line voltage. Even though, the potroom aisles and the basement are designed to be at floating or earth-free potential, some activities, such as pot shell replacement and gutter cleaning require additional safeguards for the personnel which consist of moving the earthed point to the worksite. This is usually done with a Mobile Earthing Trolley (MET) which connects a specific pot busbar to a nearby earthing post on the pot line earthing circuit.

In EGA Al Taweelah, Smart Mobile Earthing Trolley (SET) was designed, using Programmable Logic Controller (PLC), a standard high speed DC circuit breaker and fuse as well as other standard electrical and electronic components. The standard components were built in for easy maintenance. All the components are rated for 60 °C ambient temperature.

SET maintains designated pot bus bar at earth potential and interrupts the connection to earth with high speed circuit breaker within 50 ms when a second ground occurs accidentally in the potline and causes high leakage current to flow through SET. SET monitors leakage currents continuously; this gives additional information on the condition of potline insulation to earth. All SET monitoring signals are available locally on HMI and are communicated to potline SCADA through wireless devices. Operator can also enter pot number, earthling trolley user mobile numbers on HMI with the option of predefined and customized SET users to receive alarms. SET status is available on the operating floor through wireless flasher and sounder. SET control power supply is derived through UPS which maintains SET in operation even in case of potline or auxiliary power failure.

Key words: Smart Mobile Earthing Trolley, Mobile Earthling Trolley, potline leakage current detector, potline electrical safety device, grounding trolley.

1. Introduction

An aluminium electrolysis potline is composed of many pots connected in series. Modern aluminium smelters, with the evolution of high amperage smelting technology, are operated at high DC voltages up to 2000 V and currents in the range of 400 kA to more than 600 kA with typical pot voltages in the range 4.0 V to 4.5 V DC. The high potline voltages impose extra

challenges to enhance and maintain high safety standards for the personnel working in potrooms. This demands high insulation between pots and ground and continuous monitoring of leakage currents between the potline and ground. The general principles of the electrical safety in potrooms have been explained before in [1]. Here we will describe the development, testing and implementation of the Smart Mobile Earthing Trolley (SET) at EGA, which is the central piece of equipment for electrical safety in potrooms.

The maximum voltage of the potline to ground can be reduced to one half of potline voltage by fixing the potline-to-ground potential to zero ("Null point") at the middle of the potline. This is achieved by using an earthing device. In modern potlines this device is mobile and is called Mobile Earthing Trolley (MET) which, as the name tells, can be displaced from its normal position at mid-point of the potline to any other pot to make it safer to work on as discussed further on. EGA has developed an innovative earthing trolley, called Smart Mobile Earthing Trolley (SET) which has many new advanced features which increase its reliability and electrical safety in the potlines. This equipment not only keeps the local potential to earth at zero and monitors leakage currents continuously, but also interacts with operators by providing warning messages in case of abnormalities in the potline that tell them to leave the workplace for their safety if high leakage currents or voltages are present.

An important advantage of having fixed instead of floating null point appears when a second ground occurs accidentally in the potline, for example due to a pot tap-out or equipment bridging to earth. If this earth is strong, large current will pass through it and through SET with which it makes a closed short-circuit; this current will open the high speed circuit breaker or burn out the fuse in SET and interrupt the circuit before the current reaches 200 – 300 A. At this moment the potline will be grounded at the short circuit location only, making the positive and negative voltages at the rectifier unbalanced. From this unbalance, the position of short-circuit to earth can be determined. This situation needs to be investigated and corrected quickly in order to restore the earthing trolley at mid-point of the pot line.

In principle any displacement of null point from the mid-point of the potline is undesirable as it increases pot voltage to ground above half of the pot line voltage in some pots, depending on where the short-circuit to earth occurs or where the earthing trolley is installed. In worst scenario the maximum pot voltage to earth can be full pot line voltage, this happens when the earthing trolley or a short circuit is at the first pot near the rectifier, either on the positive or negative side. An example is shown in Figure 1 for Potline 3 at EGA Al Taweelah which has 444 DX + Technology pots. The potline consists of two potrooms, each having 222 pots. The pots are intentionally grounded at the mid-point of the potline at Pot 222 using an earthing trolley. The potline voltage is 1900 V. In normal situation shown, the voltage of Pot A001 to earth is - 950 V and of Pot B001 is + 950 V. If Pot A001 is earthed, the voltage of Pot B001 to earth will be + 1900 V. If Pot B001 is earthed, the voltage of Pot A001 to earth will be - 1900 V.

2. Potroom Construction

Potrooms are built for maximum electrical safety in which the principle is to keep earth away from the working zones either by distance or by insulation. Figure 2 shows zones of different electrical potentials in the potrooms: Pot potential (red), Ground (or earth) potential (green) and floating potential (blue). Floating potential is an insulation layer between pot potential and ground potential. The role of insulators is to keep the pot and ground potential absolutely separated. In the potrooms, the earth free zone extends to a minimum height of 2.5 meters above operating floor level (columns encased in concrete and covered with insulating material). Pot room basement floor is built with special cement having very high electrical resistivity such as silica cement and is at floating potential when dry or free of metal spills.

9. Personal Protective Equipment (PPE)

PPE for connecting SET, including the footwear, is usual PPE for potrooms. The footwear has to be electrically insulating footwear (British Standard BS EN ISO 20345:2004) or electric shock resistant footwear (American Standard ASTM F 2413 - 05 and Canadian Standard CSA Z195 - 02). In addition, electrically insulating gloves used for connecting SET, rated for Class 1 as per NFPA – 70 E, have to be used. Face shield, rubber mat and insulated step are rated for 2.5 kV. Gloves shall be inspected and tested for pin holes prior to each use.

10. Conclusions

As stated in [1], safe work environment in the pot rooms is generally provided by adopting special building construction materials, construction method, equipment insulation, PPE, safe working practices, training and hazard awareness. In spite of this, electrical hazards are created due to metal spillages, water ingress and high humidity causing insulation deterioration and eventually leading to insulation breakdowns. Electrical accidents happen when bridging occurs between pot potential and ground or between two different pot potentials.

The voltage from pot to ground in worst scenario can be as high as the entire pot line voltage which could be in the range of 1800 to 2000 V DC. With these voltages, workers carrying out regular pot room basement activities are at risk of being exposed to high voltages and it becomes critical to have continuous monitoring of insulation integrity of pot line and to decrease voltage to earth by using mobile earthing trolley. In this paper it is shown that fixed null point by earthing trolley is preferred to floating null point. This is achieved by connecting SET at the middle of the pot line for normal operation, thereby fixing the maximum pot- to-earth potential to ± half of potline voltage. For high risk activities in the pot room basement or on pot duct work, the local connection of the earthing trolley at the worksite increases electrical safety by bringing that pot potential-to-earth to zero.

SET is innovative potroom safety equipment with enhanced and reliable high voltage and leakage current protection, smart communication with SCADA and the operators, built with robust components and with user friendly operator interface. SET also maintains the null point during power shutdowns. Current leakage monitoring with smart alarm features, in case of abnormalities, enhances operator safety for work in the basement. However we must be aware that SET, like any other potline earthing trolley, is not personal protective equipment and even when it is connected at a work-site, usual potroom PPE has to be worn all the time, including during power shut-down.

10. References

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