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Effective insulation control monitoring system: the CANDI ™ solution for a safer production

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Abstract

The key to the chemical reaction necessary to convert alumina to metallic aluminium is the running of an electrical current through the cryolite/alumina mixture. The process requires the use of direct current, only around 4 volts but the amperage is very high, generally in the range of 180,000 to 350,000 amperes or more.
In the meantime, various interventions are required on the electrolysis cells to complete the smelting process: handling of wasted and new anode, crust breaking, alumina feeding..., interventions mainly performed by the Pot Tending Machine (PTM), electrically connected to the ground.
Thus contact with electricity while performing on the potlines may result in hazardous situation such as short circuit of the Pot Tending Machine and/or serious and fatal injuries for the operator (electrocution due to high voltage up to 2,000 volts). Hence the importance of the electrical insulation of the driver's cabin, the tools trolley and the tools themselves to avoid often irreparable situations.
To prevent such risks and above all to make the work environment safer, ECL™ designed an efficient device able to monitor the insulation level to earth and giving an audible and visual indication of abnormally low insulation values: the CANDI™ system solution.

Introduction

Needless to remind that an electrolysis hall requires in operation work on the cells including single or double anode extraction, anode hole cleaning, crust breaking, anode positioning and gauging, metal tapping, crust bath tapping...work essentially performed by the different tools of the Pot Tending Machine. During this work, some tools have to go down into the electrolytic bath to handle anode and to move near the positive risers. By accident or willfully, these tools are in contact with elements that are charged with a voltage different from the one of the earth. It is therefore crucial to have the PTM driver and the on-board equipment (in particular all the pumps and motors) electrically insulated. The CANDI™ system has been designed to provide reliable, permanent and systematic monitoring of insulation (power circuit and structure) to detect faults and deficiencies with the sole purpose to keep the operator and his machine safe.

Context

As already mentioned the key to the chemical reaction necessary to convert alumina to metallic aluminium is the running of an electrical current through the cryolite/alumina mixture. The process requires the use of direct current (DC). The voltage used in a typical reduction pot is only 4.25 volts but the amperage is very high. Furthermore, the smelting process required to produce aluminium from the alumina is continuous. The potline is usually kept in production 24 hours a day year-round. A smelter cannot easily be stopped and restarted. If production is interrupted by a power supply failure of more than four hours, the metal in the pots will solidify, often requiring an expensive rebuilding process.

Note also that as the pots are connected to each other electrically in series, the operator may be exposed in the case of a failure in the insulation of the structures and in very special circumstances to even higher over-voltages depending on the row of the cell on which the work is being done.

By driving the Pot Tending Machine, the crucial and essential tool to make the smelter work, in this environment of high temperature, strong magnetic field and large current, the operator and his machine are exposed to hazardous situation and at risk of serious injuries and fatalities such as electrocution.

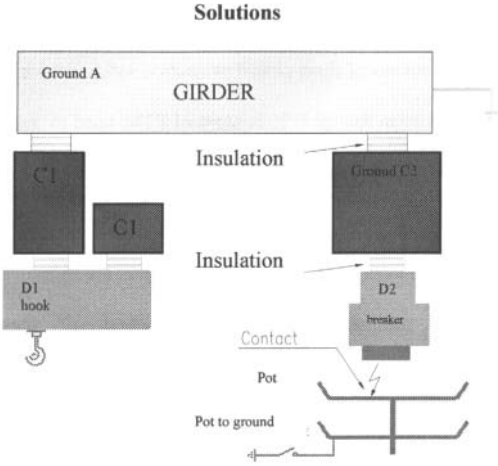

Figure 1: PTM with insulation

The PTM is composed of different grounds using separate systems of insulation. A PTM is therefore usually divided into at least four insulated parts: the driver's cabin (E), the tools trolley (C) and the set of tools (D) and finally the girders (A). Each of these zones and in particular the set of tools can itself be subdivided into sub grounds that are separated and insulated from each other (ground is taken here to mean a conducting part likely to be touched, which is not normally a live part but which may become so in the event of a fault). However it is important to comply with the rules according to which any tool in contact with the electrolysis bath (either directly, or via the anode or the cathode) as well as the cabin, must be separated from earth by at least two insulator levels. In the event of an insulation failure on one ground, the operator and equipment are protected by the non

effective insulation of the other ground. Nevertheless, the fault must be quickly located and fixed.

Between two adjacent grounds, structural insulators have been set up, placed at the mechanical surfaces (structure insulation). By means of a plurality of separation power transformers, it has been possible to transmit electrical power at the level of each ground onto an isolated circuit supplying the receivers associated with dedicated ground.

A test of the power insulation at the level of each ground and a test of the insulation of a ground from its neighbor were initially performed in particular during maintenance operations. But these were specific tests and it becomes necessary to carry out regular monitoring of these two types of insulation throughout the life of the PTM, in order to improve its safety and availability.

Until the CANDI™ system, no method or device was available to provide permanent and systematic monitoring of both power insulation and structure insulation for PTM.

Of course, permanent insulation monitoring devices are known (CPI). These are electronic devices that can detect a fault on installations in industry or hospitals. CPIs are used to cut off the electricity supply only in the event of a second fault on the installation which allows the maintenance to repair the first fault without any loss of productivity. In this method, the current is shut off by means of short circuit protection safety devices.

However, within the specific context of PTM used to work on an electrolytic cell, we have grounds which, like the cabin or the tools, must be separated from the earth by at least two insulation levels, so that the conventional operating scheme of a CPI cannot be followed. It is why ECL™ designed a specific CPI called CPI-S for Structure.

Moreover, the specific industrial context of aluminium electrolysis means that it is not possible to allow a shutdown power supply, so that it is essential to avoid the apparition of a second fault on two different grounds..

In addition, such CPI devices generally operate with voltages lower than 600V approximately while the current context of electrolysis halls demonstrates an increasing number of working pots pushing voltage at its maximum. The CANDI™ system enables to withstand current of up to 2000 volts.

Definition, purpose and principles

The ECL™ insulation monitoring device is in charge to detect, alarm, find the location of the fault in order to keep working environment and PTM driver out of danger.
This system has then two principal functions:

- To monitor the insulation structure of the PTM
- To monitor the insulation of the three phase power circuits located on the ground insulated from earth.

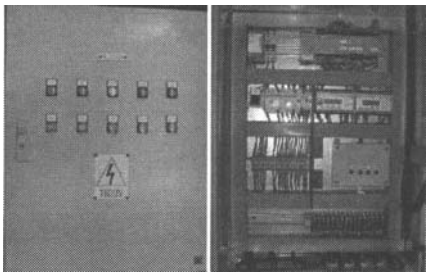

Figure 2: sample of Insulation monitoring panel layout

This system is composed of insulation monitoring devices (CPI-S)>10 Mégohms and power voltage detection relays (CPI-ac).

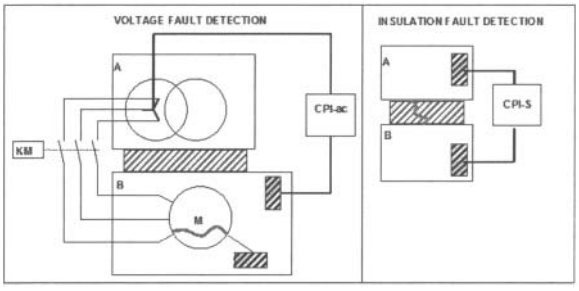

Figure 3: Composition of the CANDI™ system

Permanent and systematic monitoring
Designed with the latest technical developments and in accordance with the applicable international standards, the CPI-S is installed on PTM in a specific insulated box (80 cm × 60 cm). It measures alternately the insulation level between the grounds: A&C, C&D and C&E whereas another CPI (called CPI-ac) controls the insulation resistance of the power circuit connected to the transformers supplying the receivers located on grounds C& D.

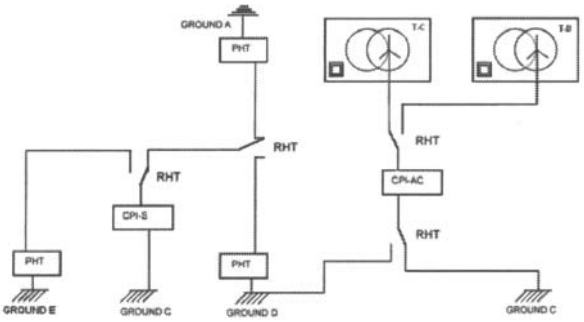

Figure 4: CANDI™ principle for two transformers & 4 grounds A, C, D, and E

The CPI-S does a sequential monitoring of the insulation level through the use of a scanning.

To new developments

To ensure the efficient operation of the CANDI™ system in such high voltage context, extra developments were necessary. For example, it has led ECL™ to design and manufacture 2000V insulated cable, specific adapter board and double insulated transformer.

Fault and alarm

Two detection thresholds are parameterized in the permanent insulation monitor intended to monitor the structure. They have been calculated taking into account the physiological effects of direct current on the human body. They depend on the maximum supply voltage of the pots, the input impedance of the measurement system and the resistance of the human body.

There is therefore:

- **An "ALARM" indication**

  This alarm informs the operator of the insulation deficiency by means of flashing lamps on the girder and alarm message on the panel view. If the measured value goes above the fixed threshold again then all the lighted signals go out. The operator can continue his work but must inform the maintenance personnel of this alarm.

- **A "FAULT" indication**

  The red indicator located on the front face of the box is then illuminated and the flash lamp operates – forces movements of long travel and cross travel to be carried out at low speed and prohibits lowering of tools monitored by the insulation monitoring system. The operator must stop his work and notify maintenance immediately.

  A structure fault stops the scanning of the A-C, C-D and C-E insulation measurements and the "zone" in which this fault has appeared remains monitored.

Two other red indicators also allow the operator to be notified of:

- A fault in the scanning system (program fault or problem at the outputs).
- The presence of faults on the CPI-S itself and/or on the high voltage scanning system.

When such fault is detected, there is therefore no longer real monitoring of the PTM structure except for cabin which highlights the safety aspect of the system in compliance with the IEC 61508 level SIL 1.

In this case, the procedures to follow will be identical to those applied for the structure fault (low speed movements, tool lowering prohibited...).

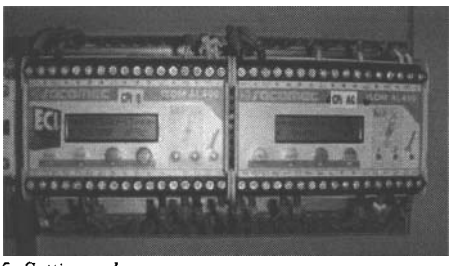

Figure 5: Setting value

As for the CPI-ac, it detects also an insulation fault on the three-phase network supplying ground C and on that supplying ground D. Each of these networks is in IT regime (impedant neutral) and even during the first fault; the operator can continue his work. This fault must be corrected as rapidly as possible.

A problem that is detected by a CPI is to be considered immediately and maintenance shall be called to correct the problem. All tools must be taking out from the pot and PTM must be stored in a maintenance area.

Today, the CANDI™ system is fully integrated to the new generation ECL™ PTM as standard equipment. Smelters have the option of setting up on cranes SIL*ver* or Gold CANDI™ system. Both in charge to detect and alarm a defect of the isolators, the GOLD option offers the additional functionality of accurately locating the fault. In addition, such system is adaptable under specific conditions to any former PTM.

Conclusion

While being a clear lever for the safety of operator, the ECL™ CANDI ™ insulation monitoring system can also be a significant advantage to avoid any production interruption and greatly improve PTM availability.

Acknowledgements

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