50 years University of Mining and Geology "St. Ivan Rilski"
Annual, vol. 46, part III, Mechanization, Electrification and Automation in Mines, Sofia, 2003, pp.95-98

DC MAINS INSULATION RESISTANCE CONTROL IN ELECTROLYSIS SHOPS

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ABSTRACT
The paper discusses the problems related to the low insulation resistance in dc mains of electrolysis shops. An analysis is made of the reasons for the low insulation resistance in these mains, the resulting risks for the workers, electric energy losses and difficulties in measuring.
A microprocessor system has been developed and implemented in the electrolysis shop at Umicor Med, which computes the leakage currents, power and energy losses, voltages to ground and the asymmetry between them.

The electric energy supplied to electrolysis baths is converted from multiphase rectifiers (16) and distributed in the electrolysis shop by copper bus bars having a 10^4 mm^2 cross-section. The voltage normally reaches up to 100 V and the current – 10 000 A.

The bus bars are opened and mounted on pedestal insulators exposed to aggressive atmosphere and the direct attack of an existing electrolyte (H_2SO_4). This situation, combined with the insulation problems of the baths themselves to ground, determine the considerably high leakage currents. It was experimentally found that at a single-pole direct short circuit the leakage current reaches up to 240A. Normally the insulation resistance to ground varies within 10^{-1} - $10^2\Omega$, beyond the range of the widely used insulation resistance control devices [1, 2]. The change in the insulation resistance as a function of time is rather dynamic.

The existing asymmetry in the voltages to ground is determined by the asymmetry of the corresponding insulation resistances to ground:

$$A = \left|\frac{U^+ - U^-}{U^+ + U^-}\right|.100,\% \qquad (1)$$

It should be noted that the asymmetry A carries information about the difference in the insulation resistance values R^- and R^+, and not about their absolute values that limit the leakage current.

$$I_y = \frac{U}{R^+ + R^-} = \frac{U^+ + U^-}{R^+ + R^-} \qquad (2)$$

The above-mentioned experimentally determined insulation resistance values and the leakage currents to ground that they limit create problems in relation to two aspects:

- Risks for the service personnel in case of a single-pole contact;
- Considerable losses of electric energy not related directly to the electrolysis process;

A quantitative assessment of these two problems can be made by using the diagram in Fig. 1.
The risks for the service personnel are related to the actually existing possibility for a single-pole contact – in contact with the current-conducting bus bars.

1. The bus-bar contact voltage "+" is:

$$U_h^+ = \frac{R_h.R^+.U}{R^+.R_h + R^-.(R^+ + R_h)} \qquad (3)$$

In contact with bus-bar "-" one gets energized:

$$U_h^- = \frac{R_h.R^-.U}{R^-.R_h + R^+.(R^- + R_h)} \qquad (4)$$

The maximum contact voltages are obtained as follows:

- In contact with bus-bar "+" and $R^- \approx 0$;
  $U_h = U$
- In contact with bus-bar "-" and $R^+ \approx 0$;
  $U_h = U$

For these reasons and in compliance with Art. 1-7-36(1) of the Regulation for Electrical Systems Design (RESD), the labor safety control authorities have recommended a maximum voltage up to 100 V.

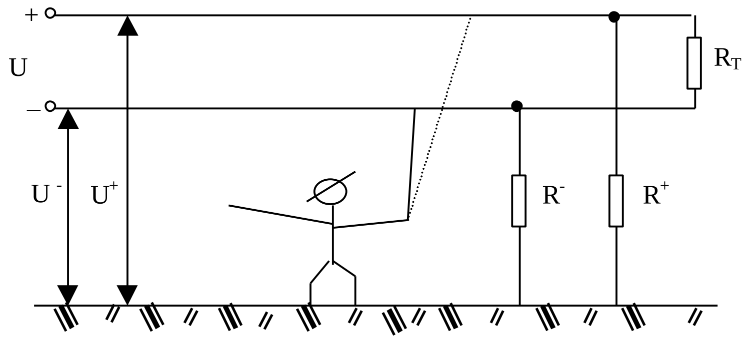

Figure 1

The supply voltage rarely reaches this value in practice since it is determined by the number of operating baths but this voltage may be exceeded thus creating real risks for humans in case of a single-pole direct contact and direct ground fault of the other bus bars. This risk situation has a very low probability but cannot be completely excluded.

Having in mind the working conditions in the electrolysis shops, it is more reasonable to adopt Art. 1-7-37 of RESD, which limits the maximum allowable contact dc voltage to 50V. This limitation is practically observed with supply voltage of 100V but only in the absence of asymmetry in the insulation conductivity to ground. This is difficult to realize in practice. In this sense, it is necessary to control both the current leaks and the voltage to ground. Since the protection switch-off is unallowable due to technological reasons, the service personnel are obliged to undertake measures with respect to the insulation resistance to ground in order to reduce the asymmetry to an extent not permitting the voltage to ground of each bus-bar to exceed 50V.

The second aspect is related to electric energy losses from leakage currents, which have a parasitic nature.
From the diagram in Fig. 1 it is easy to determine the leakage current expression:

$$I_y = \frac{U}{R^+ + R^-} \tag{5}$$

and the power expression:

$$P_y = \frac{U^2}{R^+ + R^-} \tag{6}$$

At the minimum measured insulation resistance values of the order of $10^{-1}\Omega$, which can really occur, the power loss, calculated by (6) is of the order of 10^2кW. And at insulation resistance of $10^2\Omega$, measured as characteristic, the leakage current power is of the order of several kW.

Due to the continuous nature of the technological process, the annual electric energy loss is within the range of 8.6 x10^3 to 8.6 x10^5 kWh, i.e. from 0.2 to several % of the energy consumed to perform the process.

The problems described above determined the need for developing an electrical device that can control the leakage currents and direct the attention to undertaking measures to equalize an insulation resistance value that can be used to limit the probability of a hazardous single-pole contact and reduce the electric energy losses.

The microprocessor device for measuring leakage currents KTU-M is designed to control and assess the conditions for safe operation and power and energy losses resulting from reduced insulation resistance to ground in powerful electric dc mains intended, for example, to supply electrolysis baths in copper refineries. The basic parameters of the designed apparatus are:

1. Mains voltage 125 V
2. Controlled mains current 12 kA
3. Control voltage 12 V
4.Control voltage frequency 50 Hz
5.Period of scanning the indications 6s
6.Periods accounting for the changes in the measured values:
   -For the voltages and the current (moment values) - 6 s
   -For the power from 10 measurements - 1 min
   -For the energy from 6 measurements - 6 min
7.Supply voltage 220 V
8.Output contact voltage :
   - 30 V dc
   - 120V ac
9.Output contact current 1 A

The block diagram of the device and the manner of connection to the controlled mains are shown in Fig. 2.

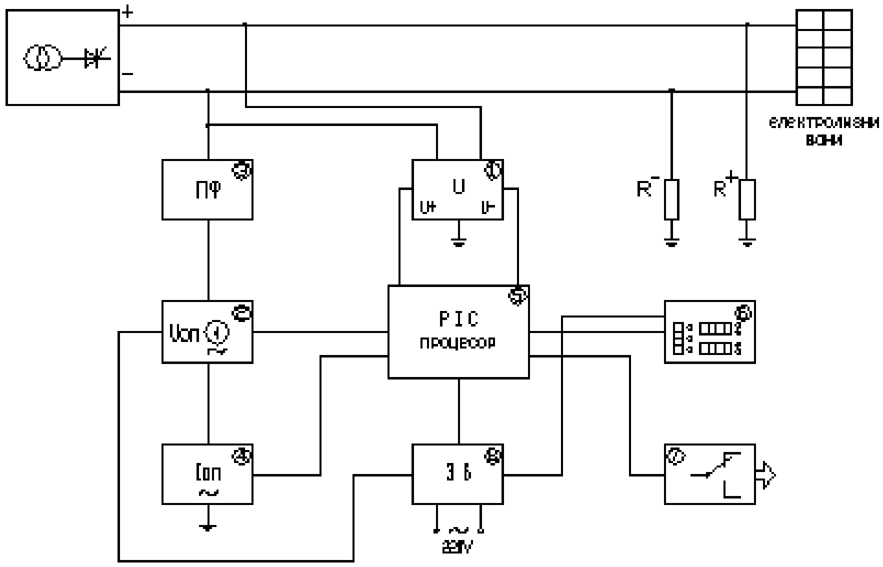

Figure 2

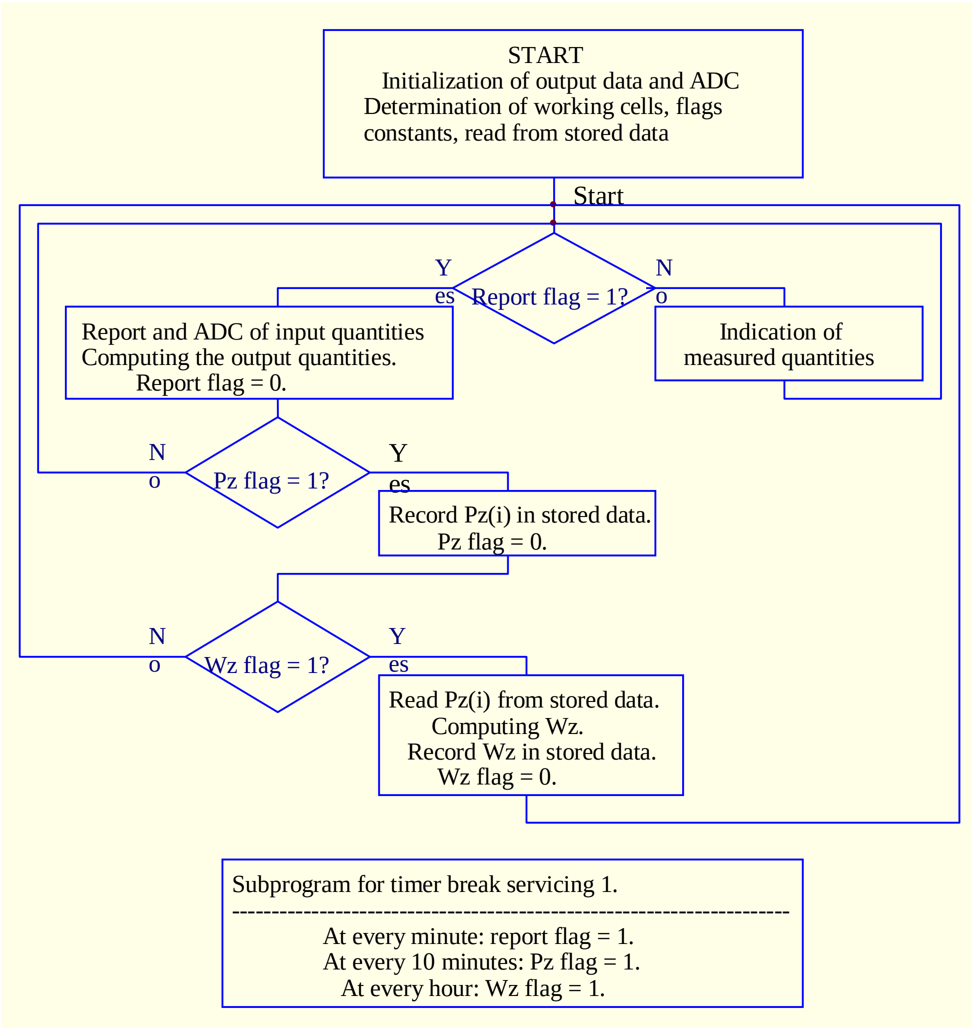

Figure 3

The basic constituent units of the apparatus are the following: Unit 1 carries out measurements of the mains voltage U and voltages to ground – of the plus bus bar “U +” and of the minus bus bar “U –”. Unit 2 contains the ac control voltage source Uоп, connected to the controlled mains by a filter 3. The control current Iоп, which is a function of the conductivity to ground, is computed in unit 4. The computing and indicating control unit 5 is built up on the basis of a PIC-processor – a new approach to the design of these devices [1, 2]. It receives data on the voltage U, voltages to ground U+ and U-, control voltage Uon and control current Ion. It also controls the indicating unit 6 that consists of two four-element digital displays mounted on the front panel, a two-color diode ladder and variously colored diodes indicating the values from the digital panels measured at any one moment. The relay unit 7 has an outlet of three switching contacts that form signals for the leakage currents to the centralized information system. The supply unit 8, connected to the 220 V mains, provides stabilized voltages for the measuring and computing units.

The insulation resistance is computed on the basis of the measured values of the control voltage and current. The leakage current and its power are determined by introducing the mains voltage and the lost energy is computed by taking into account the time. These three quantities are scanned periodically and indicated on the upper digital panel. Fig. 3 shows the algorithm of the process involving the collection of the analog data, their conversion into digital data, computing the output quantities and their indication.

A criterion for the electrical safety of the service personnel is the magnitude of the supply voltage of the bus-bar system. The latter is controlled by a two-color diode ladder: at a voltage up to 120 V the level is measured by the yellow flashing diodes. When this value is exceeded then the red diodes flash thus warning for dangerous voltage values.

The light indication is designed for three levels of current leakage values: normal – up to 10 A, higher – from 10 to 100 A and unallowable – over 100 A. These levels are subject to quantitative correction (by adjustment) and are primarily related to the increasing electric energy losses from parasitic leak currents. The signals should initiate the corresponding actions for increasing the insulation resistance to ground: washing and drying the pedestal insulators for the bus bars, removing bath leaks, etc.

The energy calculated as a current leakage loss gives an accurate quantitative picture of the damages suffered as a result of additional costs for electric energy, which has nothing to do with the realization of the technological process in recovering electrolytic copper. The four-digit indicator makes it possible to compute up to 9999 kWh so that it is necessary to reset the indications periodically. The resetting is automatic or can be done by the reset button.

The bus-bar voltages to ground are measured and the asymmetry between them is computed in % (indicated by the lower digital panel). The data allow to assess the asymmetry in the conductivity to ground and to identify the bus bar with the higher current leakage thus directing the actions towards improving the insulation resistance: at a voltage U+ < U- the higher current leakage is in bus bar “+”, at U+ > U- the current leakage is higher in bus bar “-”.

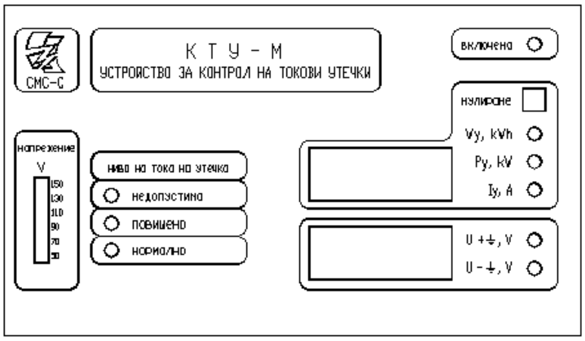

Figure 4

Fig. 4 shows the front panel of the device whose indications define fully and accurately enough the functions of the displayed elements. The asymmetry in the voltages to ground is indicated by the letter “A” preceding the corresponding number on the lower digital panel.

Figure 5

Fig. 5 shows the physical appearance of the device that is being successfully experimented at Umicor Med – Pirdop.

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Recommended for publication by Department of Electrical Engineering, Faculty of Mining Electromechanics