acta phys. slov. 37 (1987), No. 5

PLASMA DIAGNOSTICS OF AN ELECTRIC ARC BURNING IN AN ENCLOSED SPACE FILLED WITH SF$_6$

GROSS, B.,¹) VÁVRA, Z.,¹) Brno

The paper describes the determination of temperature in the plasma axis of an arc burning in an extinguishing chamber model. The arc may be considered freely burning in a space with a pressure higher than atmospheric pressure. Equidensitometric evaluation of photographs of the arc taken with a high-speed camera determined the temperature in the plasma axis and the form of the radiating plasma region.

I. INTRODUCTION

The study of the properties of the switch arc on extinguishing chamber models forms the basis of an economical design of a HV and EGV switchgear. The extinguishing chamber model [1], on which the results presented below were obtained, enables the execution of a series of reproducible experiments and monitors in their course the variations of both electrical and non-electrical quantities that characterize the rupturing process. The model allows the filming of the rupturing process with a high speed camera, thus supplementing the set of results with data about the form of the arc and temperature variations in the plasma axis with time.

The experimental equipment was designed and manufactured at the Department of Electric Machines and Switchgear of the Electrical Engineering Faculty of the Technical University in Brno where also the evaluation of the pictures from the high speed camera on an equidensitometer designed and implemented in the same Department was carried out.

II. DETERMINATION OF ARC PLASMA TEMPERATURE

The plasma temperature is determined by utilizing the dependence of the electrical plasma conductivity on temperature, the variations of arc voltage and current with time and the equidensitometric determination of the arc radius.

---

¹) Department of Electric Machines and Switching of the Electrical Engineering Faculty of the Technical University in Brno, třída Obránců míru 10, 662 43 BRNO, Czechoslovakia

The current density of the current flowing through the arc plasma is given by Ohm's law

$$\boldsymbol{J} = \sigma \boldsymbol{E} \tag{1}$$

where $\boldsymbol{J}$ is the current density vector, $\boldsymbol{E}$ is the electric field intensity vector and σ is the specific electrical conductivity.

Since in the plasma under consideration both vectors have the same direction, in further computations only their absolute values need to be taken into consideration.

The total current flowing through a plasma with a circular cross section of a radius R is

$$i = 2\pi E \int_0^R \sigma(T)\, r\, \mathrm{d}r \tag{2}$$

where r is the radius of a cylindrical plasma layer with the thickness dr. After substitution and rearrangement, while taking into account the dependences of electric conductivity on temperature, we obtain

$$\frac{i}{2\pi E} = \int_0^R A_K T(r)\, r\, \mathrm{d}r \tag{3}$$

where A_k ($k = 1; 2; \dots n$) are the coefficients of the polynomial with which the temperature dependence of electrical conductivity was approximated.

Assuming parabolic radial temperature variations, after the integration of (3) there is obtained the equation

$$\frac{i}{2\pi ER} = \sum_{j=0}^{j=n} A'_k T^j \tag{4}$$

where A'_k are the coefficients of the polynomial after integration. From equation (4) are determined the sought temperatures T, since the quantities on the left-hand side of the equation are known (instantaneous value of current i) or can be determined, respectively. The electric field intensity E is determined from the instantaneous magnitude of the arc voltage u_a and the arc length

$$E = \frac{u_a}{l}. \tag{5}$$

When applying the above relationship the voltage drops on the electrodes are neglected. This simplification is possible due to the fact that drops are negligible with regard to the voltage on the arc.

The arc radius can be determined by equidensitometric evaluations of pictures of the arc from the recording with the high-speed camera. The procedure is described in [2] and [3]. In this way also the shape of the marginal region of the radiating plasma was determined, the temperature of which is relatively low and as a consequence of this an almost zero current is flowing through this region. From the practical point of view we are concerned with a so-called mixing region in the sense of [5]. An example of the results in presented in Fig. 1, in which the internal equidensity represents the plasma that conducts the electric current and the external equidensity the marginal region.

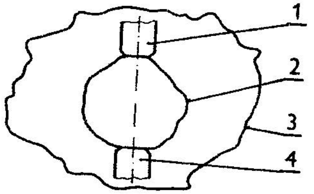

Fig. 1. Arc plasma form and marginal plasma areas at in time $t = 3.8$ ms.
1 — fixed electrode, 2 — arc plasma, 3 — marginal area, 4 — movable electrode.

The sought temperature was determined after substituting the relevant quantities into equation (4) by solving the latter according to T. The solution was carried out by iteration with the aid of a computer. The dependence of specific electric conductivity on temperature was taken from [4].

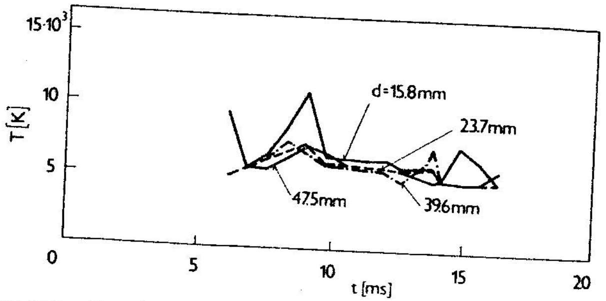

Fig. 2. Temperature versus time in arc plasma axis at various distances from the bottom contact. It can readily be seen from the figure that as a first approximation the temperature can be considered constant.

The results of the computation are shown in Fig. 2 where there is plotted the dependence of temperature in the plasma axis on time for various spacing from the bottom electrode. If from further deliberations we have eliminated the plasma regions adjacent to the electrodes, whose temperature influences the arc plasma temperature, it can be stated that on a relatively large length of the arc the temperature is almost constant. This fact allows to consider, in the first approximation the entire event as isothermic which significantly simplifies the physical and the mathematic modelling of phenomena during the burning of an electric arc.

III. CONCLUSION

The results presented serve to complete the description of phenomena associated with the burning of an electric arc in the accumulation space of a switch with SF_6 that operates on the self-blast principle. The application of optical methods of arc plasma diagnostics and the subsequent physical and mathematical processing of the results allows thus to obtain a both quantitatively and qualitatively more exact information about the course of the switching process.

REFERENCES

[1] Vávra, Z., et al.: *Research Report TZ 104*, Technical University Brno 1985.
[2] Gross, B., et al.: *Research Report TZ*, Technical University Brno 1978.
[3] Gross, B., Vostrecký, Z.: Scripta fac. sci. nat. *12* (1982), 000.
[4] Frost, L., Liebermann, R. V.: Proceedings, EEE *59* (1971), 474.
[5] Sasao, M., et al.: IEEE Transaction PAS-*101* (1982), 1115.

Received August 6th, 1986
Revised version received February 6th, 1987

ДИАГНОСТИКА ПЛАЗМЫ ЭЛЕКТРИЧЕСКОЙ ДУГИ, ГОРЯЩЕЙ В ЭЛЕГАЗОВОЙ КАМЕРЕ

В статье описан способ определения температуры плазмы вдоль оси электрической дуги, горящей в элегазовой дугогасящей камере. Предполагается, что дуга свободно горит в пространстве с повышенным давлением по сравнению с атмосферным давлением. На основе эквиденситометрического анализа снимков дуги, сделанных при помощи аппарата для скоростной киносъемки, определена температура плазмы на оси дуги и форма области светящейся плазмы.