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GLIDING ARC DISCHARGE IN THE TRIPLE-ELECTRODE SYSTEM

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A b s t r a c t. The paper presents results of investigations and discussion on the way of gliding arc evolvement in the triple electrode plasma reactor powered from the three-phase integrated system. Analysis of the inter-phase voltage courses shows that the arc discharge evolves almost equally at each par of electrodes and bring up to the assumption that electric arc converge in one point to form the "star of arcs" that has been also confirmed at the pictures taken by digital camera.

K e y w o r d s: gliding discharge, triple electrode plasma reactor.

INTRODUCTION

In recent years a great interest has been observed in the field of the utilization of gaseous pollutants released during industrial processes connected with combustion of waste materials, varnish coating, manufacture of plastics and other industrial processes. The search for the utilization method alternative to conventional ones led to the conclusion that the application of non-thermal plasma is the effective method of gas purification. For industrial applications GlidArc Plasma Reactor appeared to be a good source of such plasma. Quasi-arc discharge has been generated in the reactor that is the source of non-equilibrium plasma that takes up a considerable space of the discharge chamber, therefore chemical reactions can proceed at high volume of outlet gases and at atmospheric pressure.

TRIPLE-ELECTRODE GLIDARC PLASMATRON

GlidArc Plasma Reactor [1] can have different electrode configuration. In case of four-electrode system it consists of three working electrodes and the ignition electrode that are placed in a tubular discharge chamber. Working electrodes have been located as radii from the axis of the discharge chamber and they form the angles among each other of 120°. The electrodes have been located within the distance of 2.5 mm from the axis of the discharge chamber in the ignition zone of the arc discharge up to 35 mm at the edges of the electrodes i.e. in the area of discharge suppression. Additionally, at the ignition zone a short auxiliary electrode has been axially placed to ionize the space between the electrodes and it initiates arc discharge. Such construction of plasma reactor imposes the supply from three-phase network. Therefore, the integrated supply system has been applied that consists of four single-phase transformers suitably connected among each other and connected to three-phase with four conductors network (Fig.1).

Three equal single-phase transformers called working transformers have their windings connected in three-phase system star-star. Their task is to supply energy to the discharge chamber of the reactor. These transformers supply phase voltage in the range of 1-2 kV at network frequency. The fourth ignition transformer that provides the ignition electrode with the voltage of 10 kV and frequency of 150Hz is indispensable to initiate the ignition of arc discharge. The voltage between the ignition electrode and the working electrodes in no-load state of the supply system i.e. if no arc discharge occur among the electrodes, is the sum of the phase voltage of the working transformers and phase voltage of the ignition transformer and is given by relations (1).

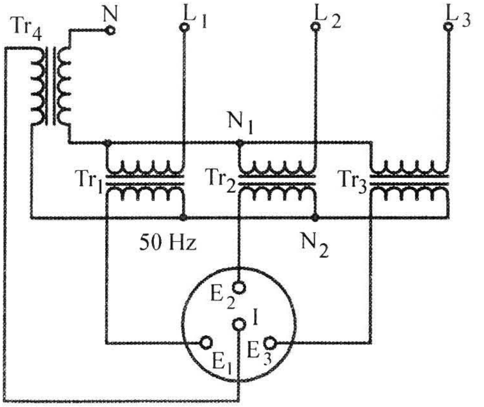

Fig. 1. Integrated supply system of triple-electrode GlidArc Plasma Reactor.

$$u_A = U_m \sin \omega t + U_{zm} \sin 3\omega t$$

$$u_B = U_m \sin\left(\omega t - \frac{2}{3}\pi\right) + U_{zm} \sin 3\omega t$$

$$u_C = U_m \sin\left(\omega t + \frac{2}{3}\pi\right) + U_{zm} \sin 3\omega t \qquad (1)$$

LABORATORY RESEARCH

Laboratory research on electric arc burning in triple-electrode GlidArc have been carried out in the meter circuit presented in Fig. 2.

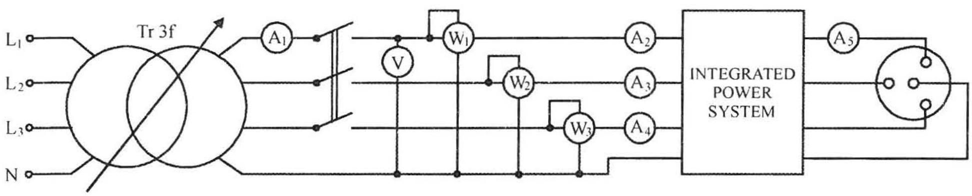

Fig. 2. The schema of the meter circuit to study triple-electrode GlidArc plasma reactor.

Tektronix TDS 380 digital oscilloscope has been used to register time courses of inter-electrode voltage. The measurements have been taken both for single-phase and triple-phase operation of GlidArc plasma reactor. The shots of electric arc taken by digital camera SONY – DCR – TRV 900E supplement the measurements.

SINGLE-PHASE OPERATION OF THE PLASMATRON

Figure 3 shows current (2) and voltage (1) courses among the working electrodes of plasma reactor at single-phase operation, for gas speed in the discharge chamber equal to 2,5 m/s. Current displacement of π rad in relation to voltage visible at the oscillograms is caused by the configuration of the measurement system. When the supply voltage reaches the value sufficient to break the gap between the electrodes the ignition of arc discharge starts causing the reduction of inter-electrode voltage. Initially, as the distance between the electrodes is about 5 mm – discharge can be treated as short arc and plasma generated in the arc as the plasma in thermodynamic equilibrium phase. This state is not maintained for a long time due to electro-dynamic forces and fast gas flow through the discharge chamber that initiate the process of discharge displacement along the electrodes and the increase of discharge volume and length. As the arc length increases even several times in relation to its length in the ignition zone, the discharge movement to the non-equilibrium phase has been observed. In this phase discharge takes the form of quasi-glow.

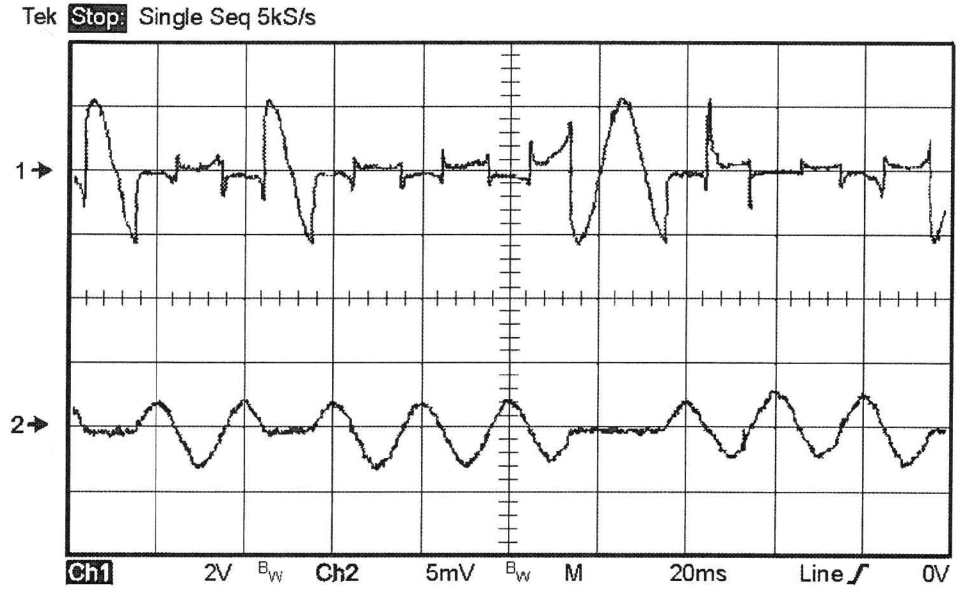

Fig. 3. Oscillograms of current and voltage distributions of plasma reactor at single-phase operation and the injection of working gas of 2.5 ms^{-1}.

Previous research revealed that 80-90% of gliding arc discharge energy has been released in non-equilibrium phase [2]. Every time when current pass zero the discharge has been extinguished, voltage polarity of the electrodes has been changed and re-ignition starts. The higher actual value of inter-electrode voltage and the decrease of current amplitude has been detected. At the moment when energy supplied from the power system is incapable to compensate power losses caused by increasing discharge, the process of its suppression starts. The speed of gas flowing through the discharge chamber is a significant factor that influences burning time of electric discharge in GlidArc Plasma Reactor. According to the oscillograms, it can be calculated that at gas speed of 1.5 ms^{-1} the discharge lasts about 140 ms (Table 1).

Table 1. Influence of gas speed flowing through the discharge chamber for single operation cycle.

Speed of gas	Duration of discharge
ms^{-1}	ms
0	Longer than 200 ms
1.5	140
2.5	70
5	60

TRIPLE-PHASE PLASMATRON OPERATION

Instantaneous courses of inter-electrode voltage for single operation cycle of triple-electrode GlidArc Plasma Reactor are presented in oscillogrames 4 and 5.

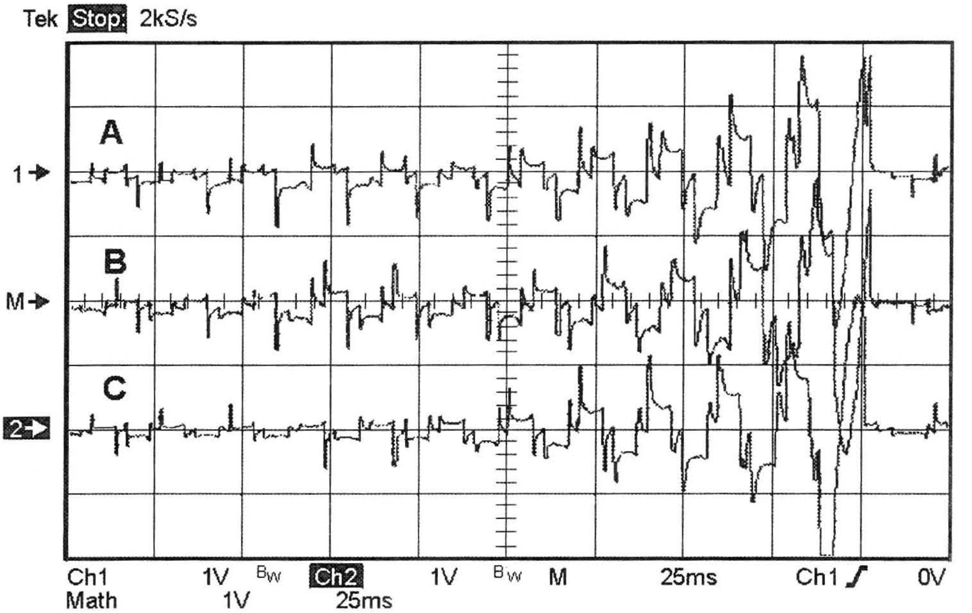

Fig. 4. Voltage courses between working electrodes of the reactor during triple-phase operation cycle at the speed of gas injection 1 ms^{-1} (case A).

Electric discharge evolves almost equally at each par of the electrodes (Fig. 4.). Two inter-phase voltages A and C show typical changes of discharge suppression. Discharge suppression of course C has been generated after clearly visible voltage impulse connected with its ignition. At one pair of the electrodes (voltage B) the arc is still burning for about 4 ms. Such courses of inter-phase voltage bring up to the assumption, that electric arcs that come out from the electrodes converge in one point to form "star of arcs" that has been confirmed at the pictures. In this case the suppression of one arm of „star" results in the simultaneous change of courses of two inter-electrodes voltages. The decay of one arm of "star of arcs" is connected with the discharge from two remaining arms that has been generated between the pair of electrodes, and the change in discharge conductance and therefore the change in the course of arc voltage. However, these changes are not visible at the oscillogram. Simultaneous change of voltage A and C that confirms arc suppression does not influence on the value of the third voltage

B. At this background the courses presented in Fig. 5. seem to be interesting. At this figure two arc discharges that proceed simultaneously whereas the third discharge is noticeably delayed can be observed. Such course of inter-phase voltages suggests that three arcs have been burning, each one between their own pair of the electrodes. This fact seems to be denied not only by the pictures taken but also the possible situation that each arc suppresses in different moment. Meanwhile, always two inter-phase voltage simultaneously show the changes connected with electric arc suppression. Such simultaneous suppression of two arcs is typical for triple-electrode GlidArc operation. Figure 5 shows voltage E with the distortions connected with the process of ignition or suppression of electric arc. Any doubts concerning the origin of these distortions are clarified in Fig. 4. Ignition impulse from the course C and instantaneous significant reduction of voltage A temporarily overlap each other. Thus, the conclusion can be made that the inter-phase voltage distortions are connected with arc ignition. The ignition of arc distorts only one inter-electrode voltage. Therefore, arc ignition at the course A distorts inter-electrode voltage C, ignition impulse of voltage B distorts voltage A and voltage C influences voltage B.

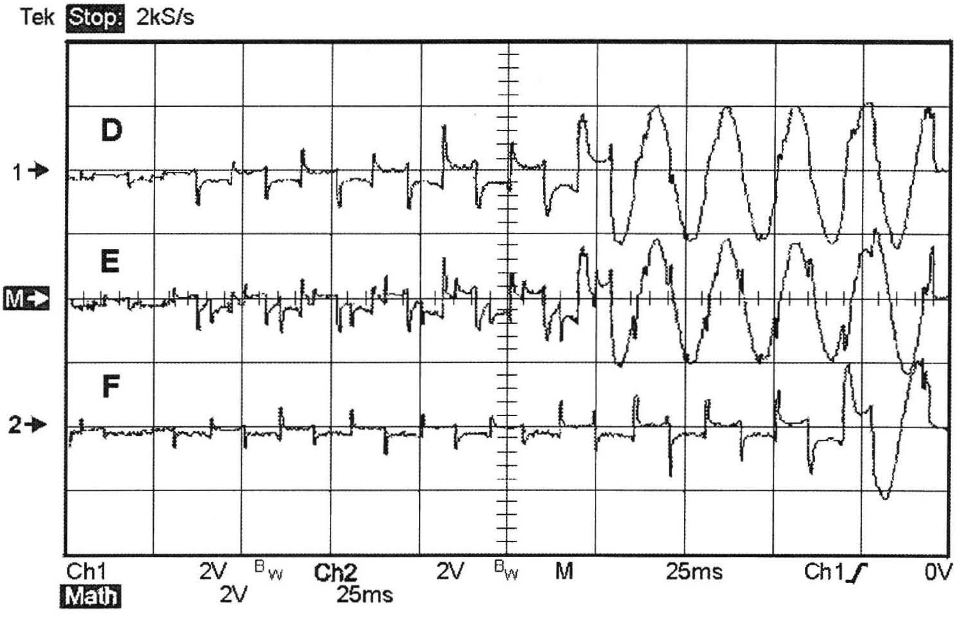

Fig. 5. Voltage courses between the working electrodes of plasma reactor during its triple-phase operation cycle at the speed of gas injection of 1 ms^{-1} (case B).

The oscillograme 4 shows that initially the ignition between one pair of the electrodes has been generated and after about 1,5 ms the simultaneous arc ignition at the remaining two pairs of the electrodes. Such a ignition process is typical for the triple-electrode GlidArc plasma reactor with the ignition electrode.

CONCLUSIONS

The conducted research concerning the way of arc burning in triple-electrode GlidArc plasma reactor does not clarify all doubts. On the basis of the obtained oscillograms and the pictures of the arc some general conclusions can be made regarding the way of arc burning and arc evolvement. The key to explain most of doubts could be the precise analysis of the accompanying phenomena of arc ignition.

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ŚLIZGAJĄCE SIĘ WYŁADOWANIE ŁUKOWE W UKŁADZIE TRÓJELEKTRODOWYM

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S t r e s z c z e n i e. W pracy przedstawione są rezultaty badań i rozważań nad przebiegiem ślizgającego się wyładowania łukowego w reaktorze trójelektrodowym zasilanym z trójfazowego układu zintegrowanego. Analiza przebiegu napięcia międzyfazowego pokazuje że rozwój łuku jest prawie równy przy każdej z par elektrod i prowadzi do przypuszczenia że łuk elektryczny zbiega się w jednym punkcie tworząc "star of arcs" , co było potwierdzone zdjęciami wykonanymi przez kamerę cyfrową.

S ł o w a k l u c z o w e: wyładowanie ślizgające, reaktor trójelektrodowy.