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Selected methods to improve the electromagnetic compatibility of the plasma reactor

Streszczenie. *Reaktor GlidArc jest źródłem promieniowanych zaburzeń elektromagnetycznych rozłożonych przestrzennie wokół komory wyładowczej jak i źródłem zaburzeń oddziaływujących poprzez tor zasilania na lokalny system energetyczny. W artykule przedstawiono wyniki badań zaburzeń przewodzonych wykonanych w torach roboczych i zapłonu reaktora oraz zaproponowano układy filtrujące. (**Metody poprawy kompatybilności elektromagnetycznej reaktora plazmowego**)..*

Abstract. *GlidArc - plasma reactor is the source of non-thermal and equilibrium plasma used to the utilization of gas dirts. The reactor is the source of radiated interference emissions around chamber of discharge and around of the power supply module. The reactor is also the source of conducted interferences propagating by the power supply module to the local power system. In this article author introduced the results of the investigations of interferences executed in the circuit of the ignition of the plasma reactor and EMC filter proposed.*

Słowa kluczowe: kompatybilność elektromagnetyczna, zaburzenia elektromagnetyczne, reaktor plazmowy, GlidArc.
Keywords: electromagnetic compatibility, electromagnetic interferences, plasma reactor, GlidArc.

Introduction

One type of the plasma reactor is a reactor with gliding arc discharge along the electrodes (GlidArc). The GlidArc reactor is in Institute of Electrical Engineering and Electrotechnologies of Lublin University of Technology (Fig. 1, 2). The quasi-arc discharge is a source of non-thermal plasma filling the space part of the discharge chamber. Plasma source and way to deliver energy to it is a forced flow of electric current in the gas. Plasma is ionized gas that conducts electricity, and this property is used in the manufacture of plasma arc. After the initiation of the electric arc is sustained by passing an electric current and can use it as a plasma source. Arcing is highly nonlinear and asymmetrical load associated with the dynamically changing phenomena of the transitional and short-circuit.

Plasma reactor

The source of plasma is an electric arc in the gas. The geometry of space (length, volume and location of the chamber) and the characteristics of the free arc plasma generated therein are constantly changing at random. It is hard to steer and control the parameters required in the processes of plasma [3,4,9].

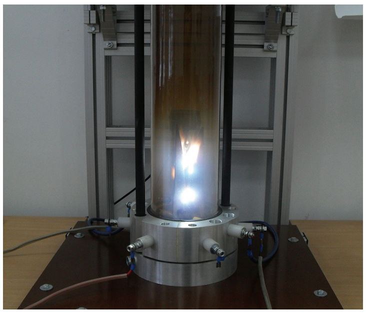

Fig.1. Quasi-arc discharge in the plasma reactor, Laboratory of Institute of Electrical Engineering and Electrotechnologies

By changing the geometry of the reactor, the composition of the working gas and power parameters can affect the electrical performance and thermal discharge in the discharge of the reactor chamber. Affecting the power of discharge, temperature plasma generated, the degree of ionization of gas, the chemical composition of the atmosphere can, in turn, shape the ongoing process of technological parameters of plasma [3,4,9].

Discharge ignition on the working electrode plasma reactor is initialized to jump from an additional electrical spark ignition electrode system (or one electrode). Depending on the type of power supply are used in two systems of ignition with single spark electrode, located centrally between the electrodes working, spark is generated directly to the working electrode, or with two ignition electrodes, placed symmetrically and between which is the main discharge of the skip on the electrode working (Fig. 1) [3,4,7,9]

Installation of the plasma reactor

Tests of the reactor installation was done in the place of its installation – in laboratory of Institute IPEE. In the institute there are several plasma reactor designs [3,4,7,9]. The research discussed in this paper has been design with few electrodes (three active - connected to power, and two ignition electrodes). The reactor works only for research. Factors working reactor at the time of his actions were nitrogen, argon, oxygen or air mixture. All factors were compressed in the cylinders and by special arrangement was directed into the space discharge. Any fumes from the combustion are removed through an exhaust system.

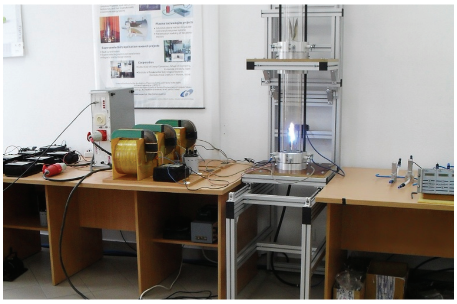

Fig.2. The Installation of the plasma reactor in the Institute IEEE

Evaluation of quality equipment from the standpoint of electromagnetic compatibility recommendations requires an appropriate conformity assessment procedure [1,7]. In the analysis of compatibility of the reactor can be used in the provisions relating to fixed installations. Treatment of the plasma reactor system as a result of the fixed nature of its work. Reactor systems are built industrial facilities dedicated to specific objects, in which there is already an autonomous pressure systems with active chemicals [3,9].

Conducted interferences 9kHz-30MHz

The analysis was conducted disturbances measured in the circuit of the reactor ignition electrodes, ranging from

150kHz to 30MHz. The main elements of the measurement system is measuring the receiver interference and a set of auxiliary equipment such as artificial networks, clamp measurement. ESCI3 (Rohde-Schwarz) used for research its complies with the requirements of CISPR 16 [2,6,7,8,11].

For EMC analysis of the reactor disturbances is necessary to know the structure of the reactor and its installation. The author established the following distribution of disturbances in the system (Fig.3).

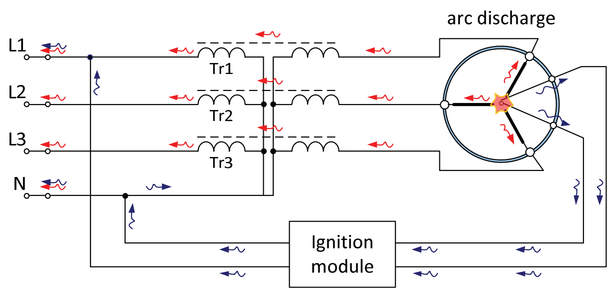

Fig.3. Distribution of disturbances in the reactor system

The first tests were made on Supply working electrode. For measuring interference used artificial three-phase network [2,6,7,8,10,11,12]. Sample results for different values of supply currents are shown below.

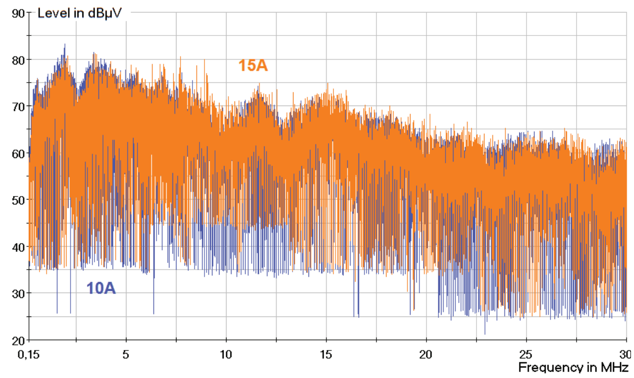

Fig.4. Interferences in the phase L1, detector AV, blue color – 10A in power system of reactor, pink color -15A

The second test were made on the supply side of the ignition module. To measure interferences the current probe EZ17 was used [2,7,11,12]. The advantage of this configuration is the introduction of the probe to the circuit without disconnecting the network, the disadvantage of lack of stabilization of the impedance of the supply network.

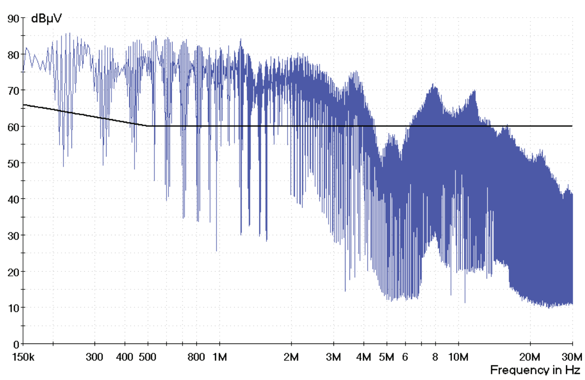

Fig.5. Interferences in modules of the ignition system, detector AV, black line – the EN61000-6-4 limit

The results are unambiguous. The nature of the measured disturbance is broadband characteristics. Nonlinear and asymmetric load, which is characterized by a plasma reactor results in exponentially on the random nature of the distribution of emissions. Limits disturbances measured AV detector for industrial equipment in the frequency range from 0.15 to 0.5 MHz are 66 dB, and in the range from 0.5 to 30 MHz is 60 dB (FCC and CISPR 22 – class A). Thus, the results show a significant excess levels.

Methods to improve EMC

The next phase of the study concerned the determination of disturbances occurring in the ignition and powers electrodes.

Basic action to protect against electromagnetic disturbances are based on the attenuation, reflection and absorption of electromagnetic wave, grounding, separation, screening and filtering. Practical protection against interference is achieved by a combination of these techniques [7].

Protection system for plasma reactor is very complex. The power supply circuit must necessarily be installed three-phase EMC filter. Tested the effectiveness of several configurations (fig.6). A similar approach is in the ignition circuit. Existing problems are problematic for the restriction. While the current flowing through the electrode ignition circuit is not too large (3 - 4A), the existing high voltage (15kV) is an effective barrier for the interference filters.

The large change in the ignition system will change the working conditions and load, which affects the effectiveness of arc. Too weak discharge cannot ignite, especially at higher supply air gases. Thus abandoned to install filters. Used to reduce distortions of ferrite components for ignition wires. The use of a single ferrite with a small volume of magnetic material (TR 16×8×13) not reduced interferences. All ferrites are the products of KE Kitegawa. Safe levels of disturbances were obtained only after installing four SFC 20-10-10 ferrites (Fig. 7).

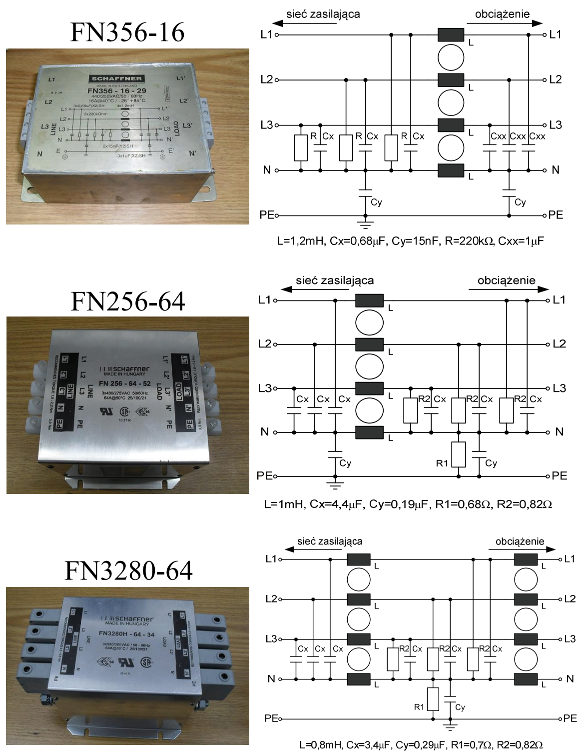

Fig.6. Testing the EMC filters in the plasma reactor installation

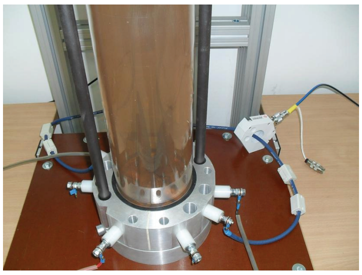

Fig. 7. The ferrites in the ignition system

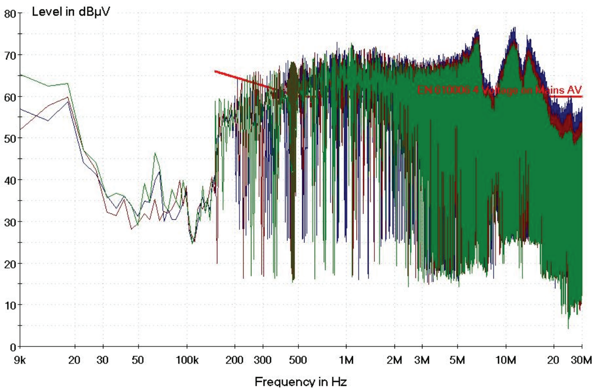

Fig.8. Interferences in the power system with the filter FN256-64, detector AV, three colors represent three phases

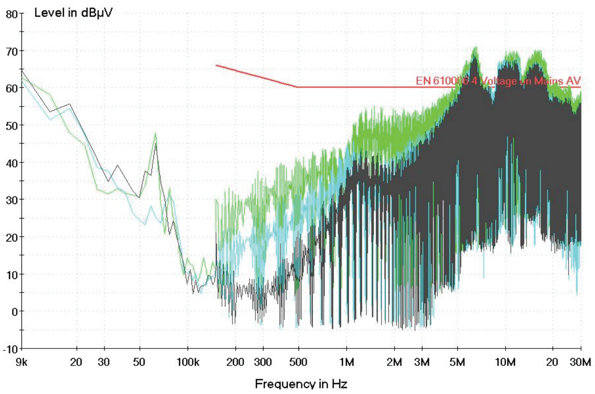

Fig.9. Interferences in the power system with the filter FN3280-64, detector AV, three colors represent three phases

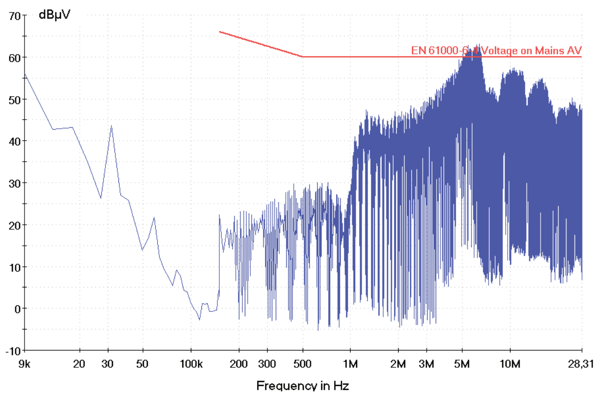

Fig.10. Interferences in the power system with the cascade connection filters FN256-64 & FN3280-64, detector AV in phase L1

Drawings from Fig 8, 9 and 10 shows the measured values of interference of the reactor installation. Choice of single filter is an insufficient means of limiting the propagation of disturbances. For this purpose, test was performed of the cascade combination of the EMC filters (FN256 and FN3280-64-64). The result obtained shows a reduction in the level of disturbance, but unfortunately there are still excess emissions.

Suppression components used next. In the ignition circuit ware installed ferrites. Only in a cascade configuration of the two filters and additional ferrites were obtained the interferences below the limits [2]. According to the directive EMC [1] the installation has obtained the CE compliance.

To increase the level of attenuation more methods are planned. First, in accordance with the practice, it is necessary to place the filters, cables and protected equipment are in a shielded enclosure. Enclosure should be grounded. These methods will reduce the noise level by more decibels [7,8,11,12].

Summary

The tests performed in the IPEE laboratory inform about the levels of disturbance generated by the plasma reactors GlidArc [5,6,7,10]. Research conducted emission (9kHz-30MHz) was carried out in two stages, the working electrode power supply circuit and the circuit ignition electrode. In both circuits had high levels of interference exceeding permissible levels. The proposed installation of plasma reactors absolutely must be equipped with systems reduce electromagnetic disturbances. In the case of disturbances conducted filtration improvement is possible by using cascading phase consisting of EMI filters, additionally supported by a specially selected ferrite chokes.

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