Influence of Transformer Design in AC/DC/AC Converter Output Circuits on Plasma Reactor Characteristics

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Three-phase arc discharge plasma reactors are challenging to maintain stable plasma parameters. Plasma performance is significantly influenced by the design of the power system and its output characteristics. This paper examines the interaction of a plasma reactor with an AC/DC/AC converter equipped with different transformer solutions to adapt the output parameters to the requirements of the plasma reactor. The design of transformers has a significant impact on the parameters of the generated plasma and the reactor's interaction with the power grid. The performance characteristics obtained for these solutions indicate that the design of the transformers has a strong influence on the performance characteristics of the reactor.

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I Introduction

The problem of supplying plasma reactors with electricity boils down to ensuring optimum plasma generation conditions, while ensuring good interaction with the power grid and limiting electromagnetic interference generated by the plasma reactor. Figure 1 shows a three-phase gliding arc plasma reactor. Reactors of this type are used in processes for the purification of gases from hazardous chemicals.

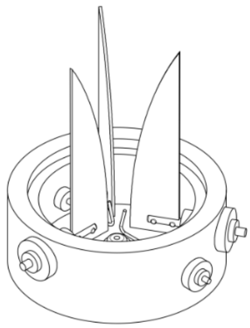

Figure 1. Costruction of the plasma reactor with gliding arc discharge

Three-phase gliding arc discharge plasma reactors are devices where stable plasma parameters are difficult to maintain electrically, physically and chemically [1]. The source of plasma, a free arc burning in a three-phase system, is the main cause of plasma instability (Fig. 2). The parameters of a long free arc plasma can change rapidly and stochastically [2][3].

Gliding arcs in three-phase systems are highly non-linear and unstable discharges that generate many voltage sinks, overvoltages and overcurrents, generate a lot of harmonics in the voltage and current feeding the plasma reactor and electromagnetic interference [4]. Due to their heterogeneous structure in cross-section and along the length of the columns of three-phase arcs in plasma reactors, they are difficult to analyse in terms of electrical, physical and chemical parameters. Furthermore, even small changes in the parameters of the electricity supply, or in the chemical or physical parameters of the plasma-generating gases, lead to changes in the conditions for the discharge to burn, which in turn involve self-regulating reactions in the plasma that change the arc structure and its characteristics.

Figure 2: Three-phase electric arc in side and top views

Control of the parameters of the plasma generated in the reactor consists of adjusting the parameters of the electrical supply, adjusting the physical parameters of the process gases and modifying their chemical composition. The regulation of plasma parameters in a gliding arc discharge reactor by means of electrical parameters is a complex, multithreaded problem and not fully understood. The shaping of the plasma parameters through the power supply system is done by selecting the voltage between DC and AC, selecting the AC voltage frequency, selecting the voltage shape, selecting the voltage and current values, controlling the harmonic content in the voltage and current. Keep in mind that the design of the power supply itself affects the discharge parameters [5]. In the case of transformer power supplies, the type of core material and, in three-phase systems, the method of connection can have an influence.

II Power Systems

An indispensable component of any power source, matching its parameters to the requirements of the receiver, is the transformer. In the case of plasma reactors, the transformer itself, in the right design, is a good and reliable power source. The transformer itself has a limited ability to influence the plasma parameters. In order to improve the control characteristics, transformer power supplies are extended with power electronic converters. Transistor converters allow the current and voltage of the plasma reactor supply to be regulated in a stepless manner, and the frequency of the voltage can also be adjusted.

Figures 3 and 4 show two solutions for this type of power supply. While both use the same AC/DC/AC converter circuit, they use matching transformers of different designs. The converter is built with a 6T+6D three-phase AC/DC transistor rectifier, a DC intermediate bus, a capacitive filter and a three-phase transistor inverter.

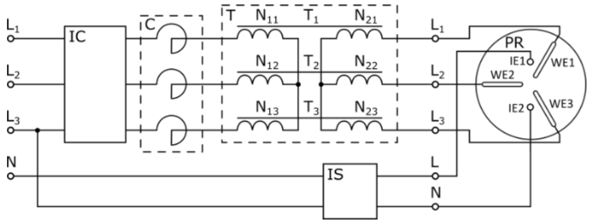

Fig. 3. Converter power supply with three single-phase transformers (PCS I)

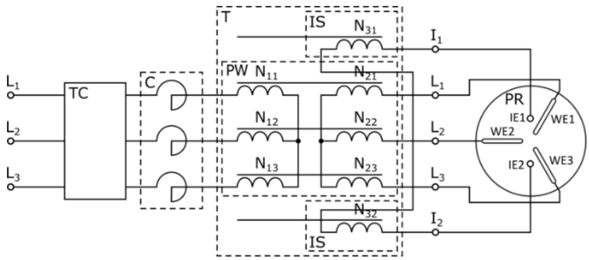

Figure 4: Converter power supply with five-column transformer (PCS II)

The PCS I power supply in Figure 3 uses single-phase transformers connected in a Yy connection group. The transformer cores were made of Metglas 2605SA1 amorphous material. Metglas cores are made as braided in the upper yoke. The PCS II power supply from Figure 4 uses a three-phase five-column transformer in a Yy connection grouping made of ET 120-27 electrical sheet. The cores are made as rolled and cut C-type. The parameters of the transformers are given in Table 1.

Table 1. Parameters of the transformers

Type	PCS I	PCS II
Power	13.8 kVA	11 kVA
Primary voltage	230 V	230 V
Secondary voltage	1.2 kV	1.2 kV
Secondary voltage of additional windings	-	1.9 kV
Primary current	20 A	15.8 A
Secondary current	3 A	2.4 A
Secondary current of additional windings	-	350 mA

Type	PCS I	PCS II
Number of turns of the primary winding	660	550
Number of turns of the secondary winding	4000	3600
Number of turns of the additional windings	-	25000

III Research on the Cooperation of Power Supplies with the Reactor

The power supplies shown in Figures 3 and 4 were tested to determine their ability to regulate plasma parameters. The results show large differences in the electrical characteristics of the plasma reactor when powered by the two power supply designs.

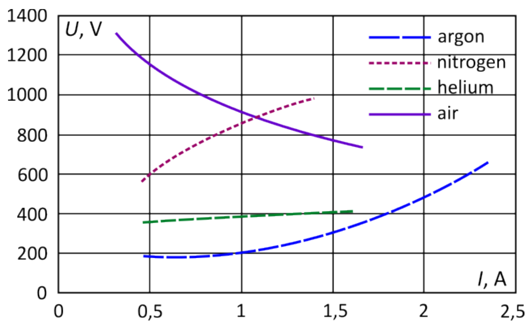

Figure 5: Current-voltage characteristics obtained for the PCS I power supply

Figure 5 shows the current-voltage characteristics for the PCS I power supply and Figure 6 for the PCS II power supply. The characteristics were plotted for four plasma-gas: argon, nitrogen, helium and air.

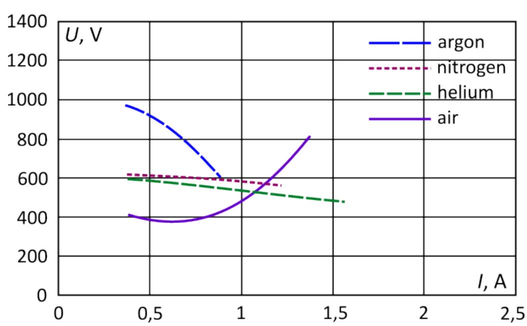

Figure 6: Current-voltage characteristics obtained for the PCS II power supply

The plotted characteristics indicate that the PCS II power supply has better control characteristics. However, taking into account other characteristics, e.g. efficiency, changes in discharge power as a function of changes in gas volume flow through the reactor, harmonic content in arc current and voltage, etc., it turns out that both power supplies have strengths and weaknesses.

IV Conclusion

The design and parameters of the matching transformer have a major impact on the interaction of the converter with the plasma reactor. The power of the transformer, the voltage and current of the secondary side, the dissipation reactance, the value of the magnetic induction in the core, the core material and the ability of the transformer to carry higher harmonics are the basic parameters to be considered. An improperly selected transformer does not allow you to take advantage of the control possibilities offered by the AC/DC/AC converter and deteriorates plasma performance. The level of electromagnetic interference, voltage collapse and overvoltage, overstress and higher harmonics generated by the plasma reactor also largely depends on the transformer design.

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