A POWER SUPPLY WITH THE POSSIBILITY OF AMPLITUDE MODULATION OF ARC-DISCHARGE CURRENT

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Abstract

For the purpose to obtain an atomic current of 2A it is required an ion current of the order of 4 to 5A. Formation of ion current of such value in an ion source on the base of arc discharge needs stable current as high as 600A, the discharge voltage approaching 100V. Thus, the supply power reaches 60kW. A special difficulty of designing an arc discharge current source is the necessity of its galvanic insulation for a total operational voltage of the Diagnostic Injector of Neutral Atoms (DI) of 50kV. Besides, it is necessary to obtain a neutral atom beam with a 100 percent intensity modulation. Such a regime is provided by modulation both of voltage of the High Voltage Power Supply (HVPS) and of the arc discharge current source (ARC PS). In so doing, the minimal arc current is chosen so that no arc discharge dies down occur during a cycle of operation of the ion source. The modulation frequency of the arc source current varies in a wide range. The report describes the design principle for the arc discharge current source and analyzes the results obtained.

1 INTRODUCTION

For producing ion current in the arc ion source the hundreds amperes current of the arc discharge is required [1]. So, for providing ion current of 5 A in the ion source for the Diagnostic Injector (DI) the required discharge current is up to 600 A. The discharge voltage at this case is 80-100 V. Thus, the power supply source of the arc ion source achieves 60 kW. In this case, because of a pulse character of DI operation (50mS) the average power of the arc current source does not exceed 1 kW. In the process of the development of the arc discharge current source (ARC PS), the requirement of its complete insulation against the total operating voltage of the diagnostic injector, which was 50 kV, was especially complex. In order to provide confidential measurements by detecting devices in experiments on diagnostic of plasma parameters in plasma devices, a possibility of obtaining the modulated beam of neutral atoms is required. The current modulation regime for neutral atoms is selected in such a way to avoid disruption («glow off») of the arc discharge during the operation cycle of the ion source. The modulation frequency of the arc source output current is varied within broad ranges from the continuous current regime during 50mS up to a 250 Hz meander.

2 ARC - DISCHARGE CURRENT SOURCE

The arc-discharge current source consists of the following basic units:

- The capacitors storage battery;
- IGBT inverter of the stored DC voltage into 10kHz AC voltage;
- insulating step-down transformer with output rectifier;
- current amplitude modulator;
- current stabilization, monitoring, and control circuits;
- control circuits of gas filling valves;
- "ignition" circuit

The ARC PS is switched on for a few tens of milliseconds prior to appearing voltage on HVPS for the DI and it is switched off upon completion of the operation cycle of the DI. The total duration of the ARC PS operation in DI does not exceed 100 milliseconds. The plasma emitter power in the nominal regime is 50-60 kW. The consumption of a few ten of kilowatts of pulse power from the power mains is inadmissible, therefore an intermediate capacitors storage of energy is used. The capacitors storage of energy consists of the three capacitors connected in series with high density of energy – "IKE 90/300" type (Russian production) with the following parameters of each capacitor:

1. U(nom.)=300 V;
2. C =2 F;
3. $R_{internal} \cong 0.35$ Ohm;
4. W max = 90 kJ.

A series-connection of three capacitors enables the charge of the storage up to the initial voltage of 900 V. An equivalent capacitance of the storage is C= 2F/3 = 0.66F; a total internal resistance of storage R_{int}=0.35*3 = 1.1 Ohm. The DC/AC voltage converter consists of two circuits connected in series: a single-cycle converter - «chopper» operated at frequency of 20 kHz and IGBT- inverter operated at the frequency of 10 kHz (Fig.1).

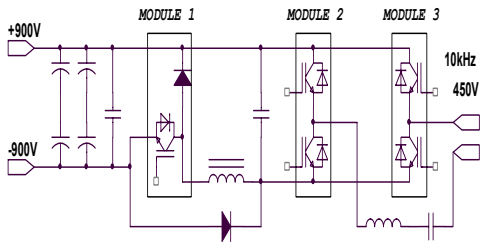

Figure 1: IGBT- inverter for arc discharge current source (ARC PS).

A single-cycle IGBT-converter (chopper) with its own independent system of voltage regulation forms stabilized controlled DC -voltage with in the range U

$_{chopper}$ = 300 ... 600V at the discharge of the capacitors battery from 900 V to 650 V. AC voltage of the IGBT – inverter output is applied to the insulating (50kV) transformer with diode rectifier to provide the arc current value up to 600 A at the voltage value of 100 V. Two identical resonant converters (Fig.1) serve for transmission of power through insulating transformers and for stabilization of the arc-discharge current. Figure 2 shows typical oscilloscope traces of output currents of resonant inverters (two channels) during operation with the arc current source of the Diagnostic Injector.

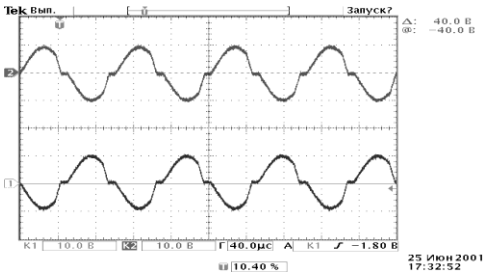

Figure 2: Output currents of the PWM-controlled resonant inverters. I_{max}=200A.

In order to provide the operation of the Diagnostic Injector of Neutral Atoms (DI) with an arc-discharge plasma emitter in the regime of 100% amplitude modulation of the ion beam energy, the synchronous with high voltage reduction and growth of the arc current is required. At the current modulation, the front duration should not exceed 10-20 microseconds and the modulation depth should be such that, on the one hand, it should not cause the arc discharge glow-off, and on the other hand, to leave a possibility of the "breakdown-less" switching on of the DI.

The AC voltages of the IGBT- inverters I1 and I2 (see Fig.3) reduced by transformers T1 and T2 with insulation voltage of 100 kV between windings and turn ratio of 3:1 down to the voltage value required for providing combustion conditions of the arc-discharge. In this case, time intervals of channel operation are selected in the following way: inverters I1 and I2 are switched on simultaneously with switching-on of all the "dummy-load" resistors.

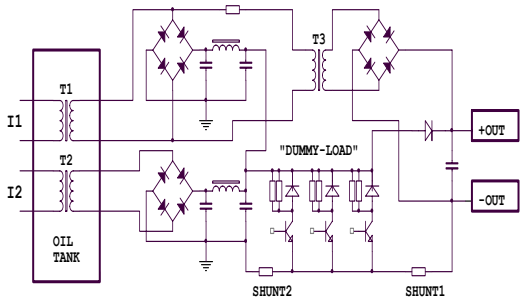

Figure 3: Components of the arc discharge current source under HV potential.

At the moment when currents in inductors of the diode rectifier filters reach their nominal values, the "dummy load" transistor switchs are disconnected causing "over-voltage" at the arc current source output thereby providing conditions of the reliable "ignition" of discharge. Simultaneously with the disconnection of the switch, the high voltage "ignition" pulse is applied and the plasma emitter starts to operate. The power of the arc discharge at this moment is given by the number of closed switches of "dummy load" i.e. by the level of current "branching" into the circuit "short-circuiting" the current source. The constant current value is measured with shunts "shunt1", "shunt 2" and the optic-fiber measuring system. Voltage measured at "shunt 2" is applied through the optic-fiber converter (as a feedback signal) to the ARC PS stabilization system. Four independently controlled transistor switches switch on the "dummy load" with discretely controlled resistance of 0.125-0.5 Ohm in the counter-phase with pulses timing the operation of HV PS. Occurrence of the discharge current in the arc ion source is initiated by applying the high voltage "ignition" pulse and by filling gas with electromagnetic valves located directly at the ion source. The cease of the arc discharge is related to switching -off of the arc current source.

Figure 4: The picture of components of the arc discharge current source under HV potential.

In the electrostatic shield (from above) there are all the power supplies at HV potential, which provide operation of the arc discharge- based ion source. In the tank filled with oil (from bottom) the step-down (Ktr = 3:1) transformers are located. The organic glass insulator (at the center) provides the high voltage insulation of components under high voltage potential (50-55 kV).

3 EXPERIMENTAL RESULTS

A Power Supply with the possibility of amplitude modulation of arc- discharge current (ARC PS) has been designed and tested in 2001; it has been operating with Diagnostic Injector. Figures 5, 6 shows typical traces of output ARC discharge current and voltage in modulated and unmodulated regimes.

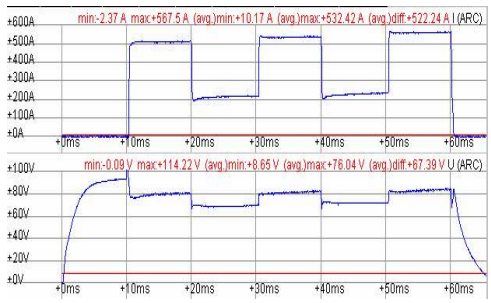

Figure 5: "ARC PS" - current source operation regime with an amplitude modulation. The arc discharge current growth (upper curve) is provided by a special correction circuit.

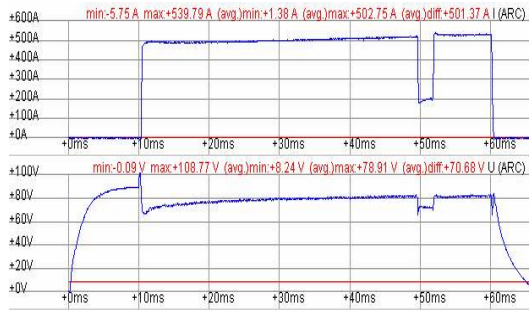

Figure 6: "ARC PS" - current source operation regime without the amplitude modulation.

4 ACKNOWLEDGEMENTS

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[1] V.I.Davydenko, A.A.Ivanov, Steady State Diagnostic Neutral Beam Injector, J.Plasma Fusion Res. SERIES, vol. 3(2000), pp. 456-459.