137 KW HV MODULATOR FOR ION INJECTOR

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Abstract

A new design technique of pulse modulators for Ion Injectors is presented.

1 INTRODUCTION

Main parameters of the high-voltage Modulator for an Injector based on quasi-stationary arc plasma emitter are presented in Table 1. The injector is intended for generation hydrogen beam of about 2 Amps current in ions. The diagnostic injector must be capable to inject a beam of neutral hydrogen of 50 kV energy necessary for investigations on plasma physics field, for example.

Table 1: Parameters of the Modulator.

Parameter	Unit	Value
Output voltage	KV	Up to 55
Output current	A	Up to 2.5
Flat-top stability	%	± 0.5
Pulse duration or output pulse series duration	Sec.	0.0005 to 2
Pulse repetition rate	Sec	≥300
Pulse rise and fall time (C_{Load} ≤ 5ηF)	µs	≤10
Pause duration between pulses in series	µs	≥500

The HV Pulse Modulator is designed for powering two grids of the diagnostic injector. The Modulator shall meet a range of rigid requirements for the output pulse shape, operation reliability at electrical breakdowns in the load and also fire security and ecological purity of applied materials. The Modulator described can generate a 2 sec. pulse or a series of pulses of shorter duration. Application of an advanced conception based on a Current Loop circuit in the design of the high voltage Modulator and using of high-power IGBT modules made it possible to construct a modulator with the required properties.

2 THE HV MODULATOR

2.1 The HV sectioned rectifier

The simplified basic circuit diagram of the HV sectioned rectifier of Modulator is presented on Fig. 1. It consists of 22 sections shown on the figure. Each section includes four subsections. The section is powered from a current-type supply source through a Current Loop shown on the left part of the figure. The power transformer in the section has five identical secondary windings. Four of them serve for charging the four subsection's filter capacitors: C1..C4. The fifth winding jointly with the switch S_9 serve for stabilization of their summary voltage. When the voltage exceeds a set threshold, the switch S9 turns ON and stops capacitors to be charged by shunting the windings of the transformer T1. This circuit is used for output voltage stabilizing.

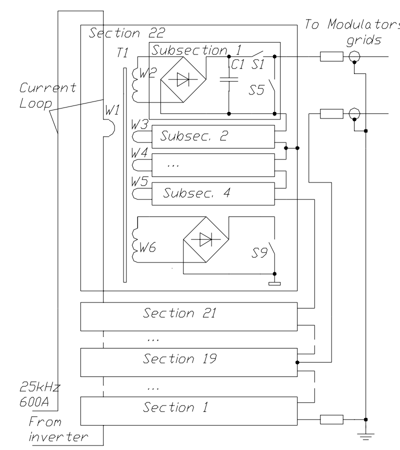

Figure 1: Layout of the Controllable sectioned rectifier

When the Modulator is generating an output high voltage pulse the switch S1 of each subsections turns ON and the switch S2 turns OFF, the capacitors C1, …C4 of all sections appear to be connected in series, and their summary voltage is applied to the load. For output current to be as high as required, the powering source current must be not lower than the last one referred to the secondary winding of the step-up transformers T. The primary one-turn windings of the transformers in all the sections are connected in series forming so called Current Loop that is fed by one Power converter. The Power converter generates AC current of a constant value. It will be presented later.

Each section generates up to 2.5 kV and up to 2.5 A. Outputs of the sections are connected in series. The number of operating sections determines the value of the total output voltage. Each section can be controlled to operation through a flexible optical cable.

For smooth regulation of the voltage fed to the injector grids, the 22[nd] and 15[th] sections have an option of smooth regulation of their output voltage from 125V up to 2.5 kV. Level of generated voltage is set by DAC-PWM signals, transmitted through additional optical cables.

Schematic design of the presented Modulator differs from known ones by holding the filter capacitors voltage near the necessary level during the whole output pulse. This allows generating high voltage pulses of any duration.

2.2 The sectioned rectifier construction

To construct the sectioned rectifier we used the circuit proposed in [2] on the base of a Current loop presented on Fig. 2.

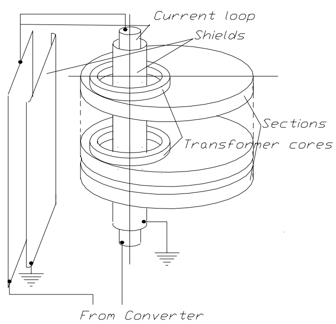

Figure 2: Schematic layout of the Controllable sectioned rectifier

Insulating air gap between the current loop and the sections was designed to operate under the full voltage generated by the Modulator. The conductor of the current loop and contents of the section are hidden from the air gap with smooth protecting shields, shown on the figure. The secondary coils are wounded on the cores.

2.3 The 25 kHz converter

The Power converter provides the Current Loop of the Sectioned rectifier with AC current. The converter is a square shape current source of 25 kHz frequency and magnitude up to 600 Amps. The shape of current curve is shown on Fig. 3.

The converter is presented on Fig. 4. It is constructed on the base of IGBT modules of BSM400GA120DN2 type of SIEMENS. The operating frequency of the IGBTs is 12.5 kHz for the current regulators and 25 kHz for the bridge converter.

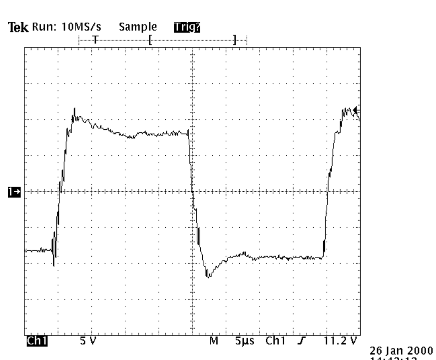

Figure 3: The Current Loop current curve at 400 A/div. (Time scale is 5 μs/div)

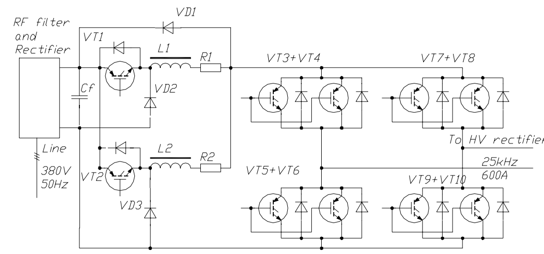

Figure 4: A simplified layout of the power converter.

2.4 The Modulator's voltage stability

Pulse flat-top voltage stability is determined by the value of filter capacitance C and switching frequency of the switch S9. It can be shown that in a steady-state mode the maximal level of voltage ripples at the output of the section will take place at Modulator's output current equal to a half of its maximal value. In this case the voltage stabilization circuit will restrict duration of the charge current with 10 microseconds in each half-period of the converter frequency. Amplitude of 50 kHz frequency ripples can be estimated in this case as following:

$$\frac{\Delta U}{U} = \frac{t \cdot I}{C \cdot U} = \frac{10 \cdot 10^{-6}\, s \cdot 2.5A/2}{10 \cdot 10^{-6}\, F \cdot 625V} \approx 0.25\%$$

Here: t - the current pulse duration, I - the maximal current of the modulator, C - capacitance of subsection's capacitor, U – voltage across the capacitor.

3 EXPERIMENTAL RESULTS

The shape of output Modulator's pulse and their front and back edges are presented on Fig.5, .. Fig.7. It can be seen short distortions on the curves of Modulators voltage pulses caused by interference in measurement circuits.

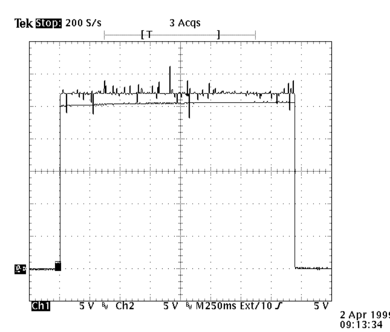

Figure 5: The Modulator output voltage (the upper curve) at 10 kV/div, the Modulator output current (the lower curve) at 0.5A/div (Time scale is 250 ms/div) Duration of the Modulator output pulse presented on Fig.5 is about 2 sec.

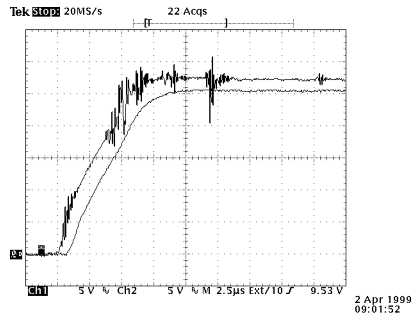

Figure 6: The rise of the Modulator's voltage pulse (upper) at 10 kV/div and the rise of the Modulator's current pulse (lower) at 0.5A/div. (Time base is 2.5µs/div)

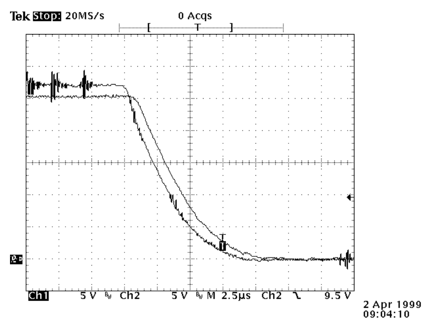

Figure 7: The fall of the Modulator's voltage pulse (upper) at 10 kV/div and the fall of the Modulator's current pulse (lower) at 0.5A/div. (Time base is 2.5µs/div)

4 CONCLUSIONS

The Modulator is used for testing Diagnostic Injectors and components of Injectors being developed at the Institute from the summer of 1999. The results of its operation jointly with the Diagnostic Injector are presented in [1].

The modulator locates in two cabinets 570x650x2100 mm and 780x1000x1850 mm in size.

REFERENCES

[1] V.I.Davidenko, P.P.Deichuli, A.A.Ivanov, V.V.Kolmogorov, Ye.M.Mandrik, V.V.Mishagin, V.V.Rashenko, N.V.Stupishin, Yu.F.Tokarev. Diagnostic injector on the basis of a stationary arc plasma emitter. Theses of reports of the XXVII Zvenigorod conference of plasma physics and controlled thermonuclear synthesis, Zvenigorod, February, p.54, 2000.

[2] A. G. Lee, Ye. M. Mandrik, A. S. Medvedko, Yu. F. Tokarev, The Current Type Hight Voltage Converter for Klystron Modulator, VII International Workshop on Linear Colliders, Zvenigorod, Russia Sept.29-Oct.3, 1997.

[3] Lee A. G., Lokhtin R. A., Mandrik Ye. M., Medvedko A. S., Rashenko V. V., Semenov E. P., Tokarev Yu. F., Pulse modulator for a diagnostic injector, Preprint Budker INP 2000-37, Novosibirsk, 2000.