KLYSTRON MODULATOR FOR INDUSTRIAL LINAC

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Abstract

Date is given on research, development and testing of the HV-modulator with the following parameters: anode voltage up to 270kV, pulsed current up to 230 A, pulse width 5 μs, repetition rate 300 Hz. Described are structural peculiarities aimed at enhancing the efficiency of pulse-forming, and results are presented of operational test on a working facility.

1.INTRODUCTION

In accordance with the program of upgrading the 2 GeV linear accelerator as injector for pulse-stretcher ring PSR-2000 [1], and, later, as warranted by the need of design and manufacture of industrial electron linacs with high average beam power and beam energy 10-15 MeV, we carry on research and development on rf-systems, in particular, modulators with pulsed power up to 70 MW and average power more 100 kW enough to drive the klystron tubes shown in Table 1.

Table 1: Main parameters of the high power klystron tubes.

Description	AURORA	ARKHAR
Operating Freq.(MHz)	2,797	2,797
Peak Power (MW)	20	18
Average Power(kW)	2.6	18
Pulse Length (μs)	2.2	3.3
Rep. Rate (Hz)	50	300
Beam Voltage (kV)	270	240
Beam Current (A)	230	220
Gain (dB)	33	37
Efficiency (%)	30	35

As was shown early[2], upon optimization of heat load thermal emission by way of modification of beam guiding conditions at the klystron and outfitting them with an auxiliary cooling system, the industrial serial klystrons can become operable at high repetition rate and pulse width as regards the manufacturer's specifications. In addition, one considerably increase the average power output, in particular, this applies to the Russian 20 MW S-band klystron "AURORA" type, upon from 3 to 24 kW (see, curve 3 in Fig.1). It must be noted that these parameters may be achieved in the case forming HV-pulse with minimum head-sag lengths.

2. DESCRIPTION OF THE DESIGN AND PERFORMANCE CHARACTERISTICS

Basing ourselves on our experience over many years with the 2 GeV linac, SLAC accomplishments and other accelerators tech information, we chose to work in our R&D on the standard linear scheme with resonance charging of a single pulse forming network (PFN) and a subrefront discharging via a thyratron switch (5 kA, 50 kV). The ultimate goal of our work was to construct piecemeal and assemble a dependable, high-efficiency HV-modulator with the main specifications shown in Table 2.

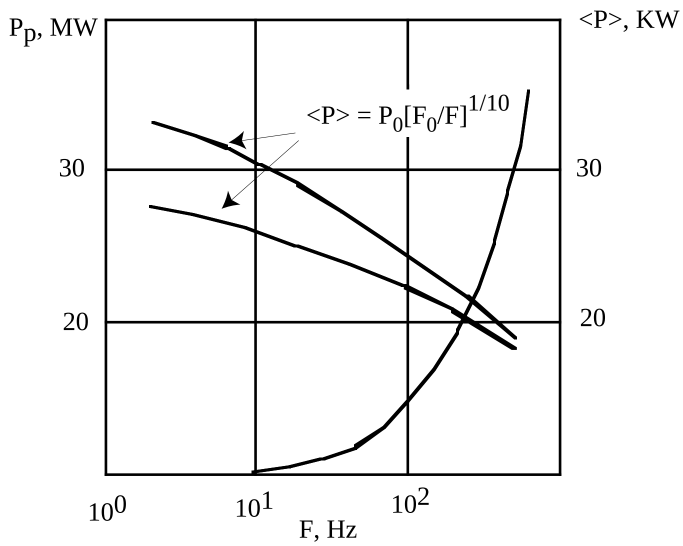

Figure 1: Experimental relationships of maximum pulsed-power operation output of klystrons of the types AURORA (curve 1) and ARKHAR (curve 2) vs. repetition rate. Curve 3 stans for average power relations of AURORA klystrons.

As is known, the most important elements that pre-determine the effectiveness of pulse shaping in a HV-modulator linear scheme are PFN and pulse transformer. In this connection, the mandatory conditions are wave resistance matching and enhanced componental undemageability at average power.

Table 2: Main specifications of the modulator.

Peak Power (MW)	62
Average Power (kW)	100
Output PFN Voltage (kV)	20
Output PFN Pulse Current(A)	3000
Pulse Repetition Rate (Hz)	300
Pulse Width (Flat Top) (μs)	4.4
Pulse Flatness (%)	±0.5
PFN Impedance (Ω)	6.5
Pulse Risetime (μs)	0.4-0.5
Pulse Falltime (μs)	1-1.1
Pulse Transformer Turn Ratio	1 : 13

In particular, experimental studies of self-inductance of industrial capacitors and its influence on the pulse-forming efficiency indicate (Fig.2) that with increasing of capacitor self-inductance (Ls) the pulse shape sustains a considerable distortion owing to an increased length of the downward curve and shortening of the flat-top. Capacitors of the IMK-45-0.027 type (manufacturer: Science Spon-Off Producer "Kondensator", Serpukhov, Russia; parameters: capacitance 0.027 μF, operating voltage 45 kV, discharge current 4 kA) with self-inductance less than 0.1 μH allow, together with employment of a strong, cell-to-cell inductive coupling[3], for pulse-forming with minimum head-sag lengths and pulse height deviation from flatness less than 0.5 %. Besides, additional dedicated R&D secured a vital decrease in heat losses in the above capacitors, in other words, a possibility of their utilization at high average power.

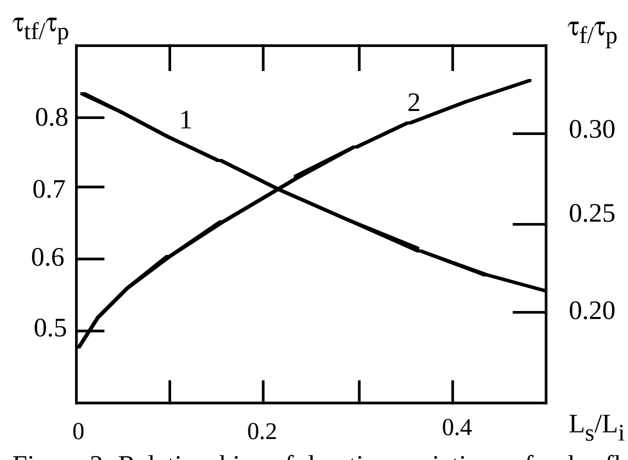

Figure 2: Relationships of duration variations of pulse flat-tops (curve 1) and downward declining (curve 2) during changes of the residual inductance of the capacitors.

Similarly, the pulse-forming efficiency is affected by an increased diffusion inductivity of the pulse transformer, in other words, a lessening of inductive coupling between windings. In our design version, we employ a ribbon-type conductor for the primary winding upon which is supliposed the secondary in proportion 1 primary to 2 secondary turns. Such setup permits, as is the case with low-voltage transformers[4], the considerably decrease the diffusion inductivity which gives much room for diminishing the effect the pulse shape distortion.

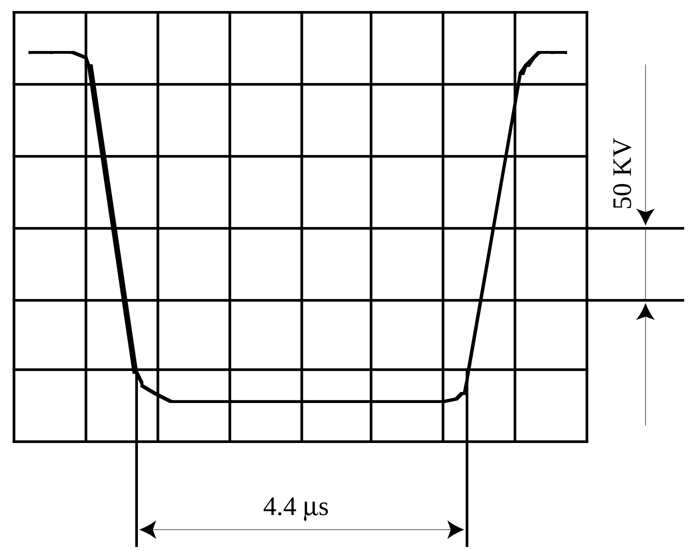

Figure 3: Oscillographic image of klystron HV- pulse in operation mode.

3. CONCLUSION

These results. as well as results from other research studies, laid the groundwork for blue-printed design work and building of prototypes.

The operating prototypes of HV-modulators, whose parameters are given in Table 2, have met all design specifications with pulse-forming efficiency > 85 % and total efficiency > 75 %. They have been operated with industrial accelerators for over 3000 h and displayed the necessary dependability and parametric stability.

4. REFERENCES

[1] V. Boldyshev, P. Gladkih, V. Gonchar et al. Project of Circular Stretcher of the KPTI 2 GeV Electron Linac - Proc. All-Union Seminar "Electromagnetic Interaction of Nuclei at Low and Medium Energies", Moscow, 1987, p. 273.

[2] V. Beloglazov, A. Dovbnya, V. Krivchykov et al. Parameters of Accelerator RF-Supply Sources for Non-Standard Operation Regimes - XIII Conf. on Charged Particle Accelerators, Dubna,1992, p. 64.

[3] M. Gladkih, A.Dolgov, V. Krivchykov et al. A High Precision Pulsed Modulator with an Arbificial Bias on Vario-Couplers, PTE, 1985, vol.3, p.619.

[4] A.Kulynich, A. Semenov. Pulsed Transformer, Patent USSR # 551712, 1977.