MOSCOW MESON FACTORY DTL RF SYSTEM UPGRADE

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I. INTRODUCTION

The Drift Tube Linac RF Power Supply is a critical system in the Moscow Meson Factory (MMF) complex operation. Recent activity in its modernization is under discussion in this paper. DTL RF system consists of 5 identical channels plus reserve one. Every channel includes the four-stage 198,2 MHz amplifier, two anode modulators (one of them for the first two amplifier stages on the valves GS-31B and the other for the two output stages on the valves GI-51A and GI-54A), coaxial system, phase and amplitude automatic control systems (Fig.1).

The RF system was designed nearly twenty years ago in the Radiotechnical Institute of the USSR Academy of Sciences and fully discussed in a broad list of publications. The most detailed description of RF equipment was presented in [1-6].

The main reasons, which have caused the need of RF system modernization are the following ones:
- a low reliability of the valves GMI-44A and GI-54A in the modulator and RF amplifier output stages;
- a self-excitation of the output stages of the RF amplifier;
- a long RF power turn-on transient.

The results of the RF system efficiency improvement are described below.

II. THE RESERVE RF POWER SUPPLY SYSTEM

The DTL RF Power Supply System comprises one reserve channel. In accordance with initial design the entire equipment of the reserve channel may be connected to any of five DTL tanks instead of the failed channel. For that purpose five p -i-n switches have been used, which provide fast connection of the reserve channel instead of the failed one. In a course of this procedure the tank begins to operate with reserve modulators, RF amplifiers and amplitude and phase circuits. It was inconvenient because of the need to calibrate and readjust the amplitude and phase control system circuits of the reserve channel.

Recently the only powerful elements (HV-rectifier, modulators and RF amplifiers) of the reserve channel are connected to the cavities using the double phase-regulator with the switch [5]. It is reasonable since the powerful elements are the causes of failure in most cases. The failure of the amplitude and phase control system elements happens rather rarely, so the amplitude and phase control system elements native to the given tank are never replaced (Fig.1). Now the time to put the reserve channel into operation instead of the failed one does not exceed 25-30 minutes.

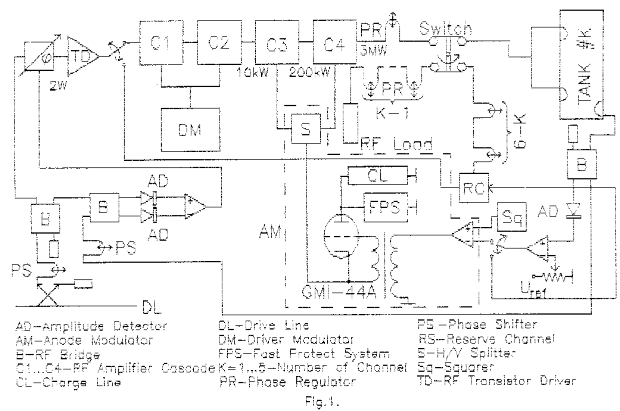

Figure 1. The Reserve Channel Block Diagram

III. INCREASING THE RELIABILITY OF THE RF AMPLIFIER AND MODULATOR OUTPUT STAGES

In the last years some R&D works were initiated in NPO "Toriy" (Moscow) and AO "Swetlana"(S. Peterburg) to develop new more reliable powerful valves for the last stages of the AM modulator and RF amplifier using modern materials and technologies. In the last year powerful water-cooled triodes "Takt-1" were installed in the modulators AM of the channels $N2, 3$ and 6. Use in them the high efficient electron optic with tape-like electron flows and deep cooling grids allows to apply the high anode voltage and operate large anode current. In addition to that VA characteristic of the valve is near to that of pentode with the low anode voltage drop. The main parameters of the valve "Takt-1" are presented in the Table 1.

The new pulsed powerful RF triode "Katran" (AO "Swetlana") with pyrolytic graphite grid is tested now as well. To investigate the new valve operating on any of the five DTL tanks it was installed in the output stage of the reserve channel. Results of the "Katran" tests have shown that it has the higher then GI-54A breakdown voltage and more reliable cathode heater; new valve has not experienced selfexcitation when the grid driving power is off, which was typical short-coming for a GI-54A. That advantage of "Katran" opens a possibility to control RF power in DTL tank changing the level of the grid driving. The main parameters of the valve "Katran" are presented in Table 2.

IV. IMPROVEMENT OF CHANNEL OPERATION

After beginning a routine work of all RF system channels it was found that there are a lot of cases of a selfexcitation at the low frequencies (a few MHz) in output stages of RF amplifiers, which could switch off one or a few channels due to interfer-

Table I
The Parameters of the "Takt-1" valve.

N	Parameter	Unit of a measur.	Quant.
1.	Anode pulse current when grid-driving pulse is 5 kV and anode voltage - 10 kV	A	750
2.	Maximum anode dissipated power	kWt	300
3.	Maximum anode voltage	kV	100
4.	Grid/anode currents ratio		0.05
5.	D.C. grid bias	V	-50
6.	Filament power	kWt	2.8
7.	Filament A.C. voltage	V	28
8.	Weight	kG	45
9.	Sizes: height diameter	mm mm	625 300

Table II
The Parameters of the "Katran" valve.

N	Parameter	Unit of a measur.	Quant.
1.	Operation frequency	MHz	200
2.	RF pulse power at anode voltage 40 kV	MWt	4
3.	Power gain		10
4.	Maximum anode dissipated power	kWt	140
5.	Filament power	kWt	16
6.	Filament A.C. voltage	V	16
7.	Duty factor		0.05
8.	Weight	kg	45
9.	Sizes: height diameter	mm mm	460 625

ence on timer or p -n-p-n switch in the modulator fast protection circuits. The main cause of the selfexcitation was a coupling between two output stages due to common anode power supply circuit. Since the power gain in the last two stages achieves 30 dB the danger of a selfexcitation is very real one.

After the channel is turned off due to self-excitation it takes a long time to restore the nominal level of power in the tank - from 5 minutes for tank N 1 up to 15 minutes for tank N 5. That is why a much effort was spent to investigate the reasons of a selfexcitation and to find the ways to prevent it and its consequences. The following measures have been taken:

- check up and restoration all of welded seams in the two output stage of the RF amplifier;
- change in the modulator AM timing circuits;
- installation of "electronic gate" network in the timing circuit all of modulators aiming to lock the input in a pause between the timer pulses;
- inserting of the LR dumping cells S (Fig.1) which provide decrease of coupling between anodes of GI-51A and GI-54I.

After fulfilling of the above mentioned measures the RF system began to work much better. So, if during the first beam production shifts in 1989 the mean time between two breakdowns was about $1h$ and the maximum time - $3h$, then in 1994 those figures have reached $9h$ and $45h$ correspondingly. A few channels simultaneous breakdowns have been practically excluded, though previously they happened in 90% of all breakdown cases.

V. IMPROVEMENT OF THE RF POWER TURN-ON TRANSIENT

As it was said above it is difficult to cease entirely accidental switching off of the channels and hence there is a need to take measures to decrease a RF power turn-on transient in a tank. Its duration is determined with noticeable drift tube thermal changes due to RF power dissipation and it takes a time to decrease the temperature of cooling water to keep the cavity resonant frequency. In detail the problem was discussed in [7] where the temperature gradients between copper and cooling water are presented. They are changed from $1C^{\circ}$ (in the tank N 1) to $8C^{\circ}$ (in the tank N 5). Since the relation between a resonant frequency and drift-tube temperature is determined as a linear dependency with the coefficient $K = 1.5 \div 2kHz/C^{\circ}$ and drift-tube thermal time constant does not exceed 30 sec then the tank will be detuned entirely through $20 \div 30sec$ after the channel is switched off. A slow resonant frequency control system can not help because the only pure delay in a control loop achieves $20 \div 25sec$. To decrease a RF power turn-on transient the special program was developed which fulfills the following operations:

- analyses a cause of the accidental switching off of the channel;
- creates the program control command to switch on the failed channel if the accidental turning off was connected with interferences on timer or p-n-p-n switch in the modulator fast protection circuits;
- keeps the same cooling water temperature for a time approximately equal to three drift-tube thermal constants.

The program allows to decrease a turn-on transient from $5 \div 15$ min to $1 \div 1.5min$.

VI. CONCLUSION

Above mentioned investigations and debugging of the RF system equipment have increased its efficiency noticeably. We are going to continue the works directed on increasing the reliability of the RF system on account of an installation of the new valves "Takt-1" and "Katran" in every channel, optimization of the RF amplifier output stage tuning and decreasing of the interference on the timer and p-n-p-n switch in the modulator AM fast protection circuits.

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