MAGNETIC FIELD FLAT-TOP OF YEREVAN SYNCHROTRON

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Abstract

One of the main tasks of the Yerevan Synchrotron modernization is the creation of long mono energetic extraction of the accelerated beam with a high duty cycle. To achieve this, the optimal solution is the improvement of the magnetic field to form a long flat-top as the first stage. At present the Yerevan Synchrotron power supply provides a flat-top magnet field with a duration of 6 ms. The two methods to obtain a flat-top of long duration up to 100 ms, which would provide a sufficiently high duty factor of 70%, are presented.

Physical starting of the magnetic field flat-top of the Yerevan synchrotron (of 4 ms duration at accelerated beam energies from 2 to 4.5 GeV) and slow ejection of particles were executed in December 1987. In this mode there was studied the operation of all units of the accelerating complex and were determined the basic specifications to the creation of plateau formation system of 20 ms and higher duration.

The slow ejection plateau was formed by the method of "cutting" of alternating-current component of the electromagnet [1]. To do this, at the moment the electromagnet current achieves the given value the resonant circuit capacities C1-C16 and the additional chokes L_1-L_{16} are shorted by means of the thyristor keys T_1-T_{16} (Fig.1).

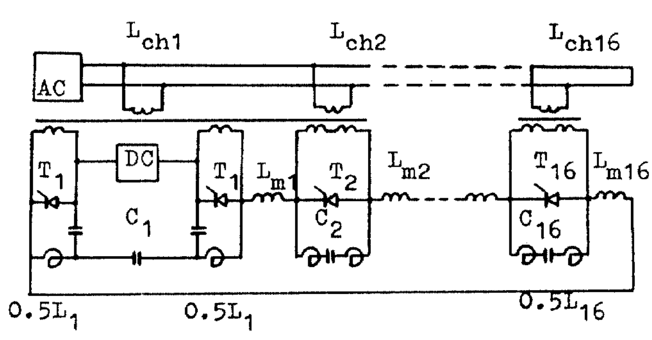

Fig. 1.

L_{ch} - choke inductance
L_m - magnet inductance
AC - alternating current
DC - direct current

Fig.2 shows the diagrams of currents and voltages in the elements of resonant circuit in the field plateau formation. The shunting keys T open at the moment when the current in the electromagnet I_m has not achieved a maximum yet, and the alternating-current voltage on the capacitor banks in positive relative to the shunting keys anode. The flat-top duration of the electromagnet current can be found by the formula:

$$\tau = \frac{2}{\omega} \arctan\left[\sqrt{\frac{L_m}{L}} \cot\varphi\right]$$

where:

$\omega = \frac{1}{\sqrt{LC}}$ - is the circular frequency of the circuit produced when the shunting keys are switched in.

φ - is the initial phase of flat-top formation.

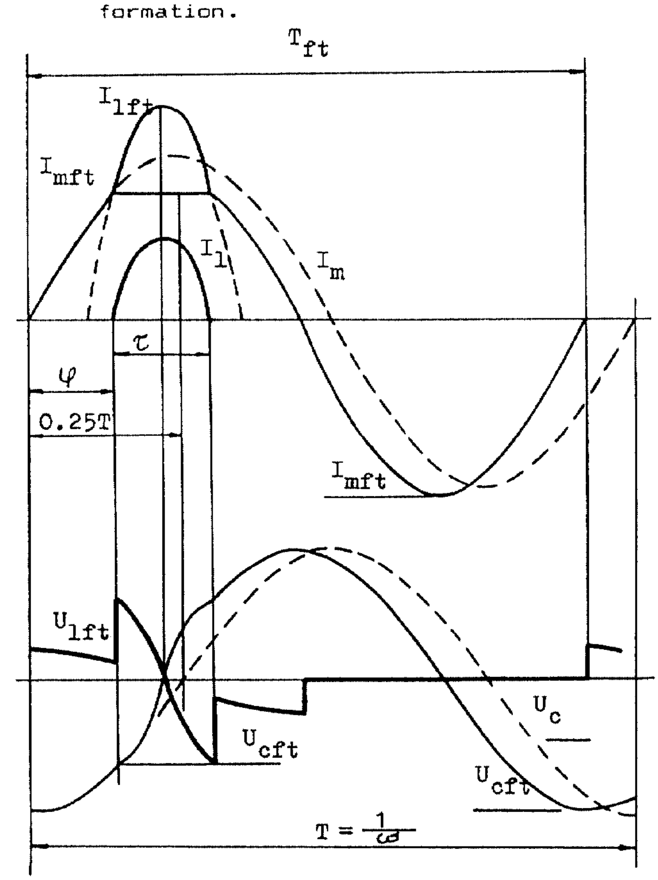

Fig. 2.

U_c, U_{cft} - capacitors bank voltage
U_l, U_{lft} - choke voltage
I_m, I_{mft} - magnet current
I_l, I_{lft} - choke current

During the experiment there was determined the flat-top optimal duration dependence from the condition of minimal losses in the system for the different modes of accelerator operation. The generalization of the experimental results has shown that for the real parameters of the system at the magnitude of additional inductance equal to 15% of inductance of resonant group the current plateau optimal duration must be about 3 ms. This leads to the increase of total losses in the power supply system by 20%. The greater portion of additional losses is due mostly to the losses in the concrete chokes and new cable communications.

The experiment has shown that the short-circuit of the capacitor bank induces high-frequency oscillations (15 kHz) in the electromagnet field which are caused by the discharge of spurious capacitances of the resonant circuit through the electromagnet. These magnetic field disturbances result in excitation of synchrotron oscillations and thereby complicate considerably the electron beam ejection. In view of this, the above-described circuit was improved in order to obtain a possibility to form plateau at zero voltage on the resonant circuit capacitance (Fig.3). As soon as the electromagnet current achieves a maximum value (when $U_c = 0$), the resonant circuit

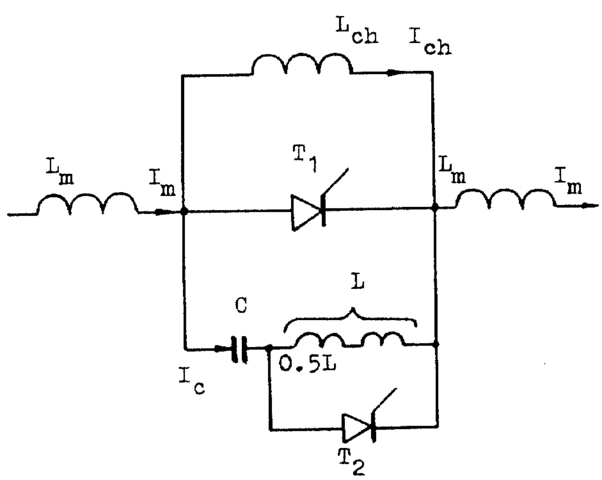

Fig. 3.

capacitance and the additional inductance L are shorted out by the thyristor T1. To accomplish the current plateau, the thyristor T2 is switched on at the capacitor voltage negative half-wave, thus inducing reverse current to lock the thyristor T1. Short-circuit interruption is realized the transient processes due to the possible asynchronous commutation of some groups come to an end by the moment of the next injection. This circuit allows one to form the magnetic field flat-top of 6 ms duration without special sources for the compensation of current fall-off in the electromagnet.

With the aim of further enhancement of the accelerator operation efficiency, at present a circuit is being designed which will provide the formation of the flat section of the synchrotron magnetic field of 50 ms and higher duration with the expected duty factor >=70% [2].

As long as some units in the accelerating complex including the injector are energized from the commercial supply line, the synchronization of accelerating cycles with the supply line frequency ensures steady initial conditions of injection and capture of particles in the accelerator, which allows to remove the beam intensity beats on the accelerator output (such beatings were observed in some synchrotrons with different frequencies of the resonant circuit and the supply line).

Two alternative circuit of frequency synchronization were test-operated on the Yerevan synchrotron. In the first version the synchronization is realized owing to the change of equivalent inductance of the resonant circuit, by means of a series or parallel connection of additional inductance. The moment for switching additional inductance in each period is chosen automatically as a function of the difference between the periods of supply line and the circuit. In order to exclude the influence of transient processes on the guide magnetic field at the moment of switching on the additional inductance during particle acceleration (high frequency oscillations on the spurious loops of the circuit, change of the reactive part of impedance of the circuit, etc.), the half-period corresponding to the electromagnet current fall-off is chosen as a preferable (allowed) synchronization region. The value of additional inductance to provide the synchronization region required makes up 10-15% of the equivalent inductance of the resonant circuit.

In the second version the synchronization is realized via the change of pause duration between half-periods of voltage on the electromagnet as a function of the difference between the periods of the resonant circuit and the supply line. The circuit allows to form the pause in the electromagnet voltage for both a positive and negative half-wave of the electromagnet current.

The separation of functions of plateau formation for the slow ejection and synchronization of the resonant circuit frequency with the supply line frequency with respect to the different half-periods of the electromagnet current enlarges the possibilities of the circuits of synchronous power supply of the rapid cycling synchrotrons. In reconstruction of operating accelerators with the aim to form the plateau of ejection and synchronization with the supply line the minimization of the equipment is determinate. The circuits based on shunting of the resonant circuit by a thyristor key with additional inductance in the capacitor circuit answer this requirement most adequately.

References

[1] V. P. Goncharenko, H.A.Martirossyan et al, "Physical starting of the first stage of the current plateau formation system of the circular electromagnet for the "EKU-6" synchrotron slow ejection", Proceedings of the 11th All-Union Charged Particle Accelerators, Dubna, 1988.

[2] W.Bothe, H.A.Martirossyan, "Flat-top modes of Yerevan synchrotron operation", DESY M-88-14, November 1988.