DYNAMIC STEERING SYSTEM OF KEK 12 GEV PROTRON SYNCHROTRON

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Abstract

At the KEK 12GeV PS, DC steering system for closed orbit correction was replaced by dynamic steering system. In the new system 28 horizontal and 28 vertical magnets can control the closed orbit from injection (500MeV) to extraction (12GeV). Each steering magnet can be excited in any excitation pattern independently. These are controlled by VME computer network.

Introduction

Before the displacement closed orbit was controlled only during the injection period, where the beam size was largest during the acceleration cycle. But as the beam intensity increased recently, the beam losses at the phase transition and at the early stage of acceleration increased noticeably. Then we needed new system to control closed orbit and maintain the largest aperture from injection to extraction. In addition to this, we have plan to increase transition energy during the acceleration (we call it variable γ_t) to avoid the beam loss at the transition crossing [1]. At this case we will introduce strong perturbation quadrupole magnets to modulate dispersion function. Such a system may reduce the aperture tolerance greatly. Then we will have to control closed orbit with an accuracy of 1 mm. The other purpose of introducing dynamic control, is to control the vertical orbit of slow extracted beam at the top energy. Further in the special case of polarized proton acceleration, closed orbit must be controlled at the imperfection resonances during the acceleration to conserve the polarization [2].

Before this installation, vertical and horizontal closed orbit was controlled with 28 steering magnets with DC power supplies for each direction only at the injection. And at the early stage of acceleration, horizontal closed orbit distortion due to the eddy current at a bending magnet was cancelled with back-leg winding of one bending magnet with programmable power supply. At this replacement the magnets were not changed because each steering magnets are constructed with beam position monitors in one unit. So the upgrading was the installation of new high power programmable power supplies and their control system by VME computers.

Steering magnets and position monitors

All of the steering dipole magnets had laminated steel cores, and was sufficient for dynamic system. Parameters of steering magnets are listed in Table 1.

Table 1 Parameters of steering magnets

magnets parameters	II-2F & I-1D	III-2F	other 53 magnets
gap (mm)	350	160	230
length (mm)	200	190	200
width (mm)	300	150	230
coil turn	3340	3000	2200
resistivity** (Ω)	9.2	6.5	6.3
inductance** (H)	3.7	1.7	1.5
maximum field (mT)	78	153	78

** These parameters include contributions of cables from power supplies to magnets.

KEK 12GeV PS is consist of 4 superperiods, and each superperiod is consist of 7 FODO cells as shown in Fig.1. Twenty seven horizontal steering magnets follow the main F quadrupoles except for III-2F and one horizontal steering magnet is placed at III-1D short straight section (in Table 1 we refer III-2F to this steering). Twenty eight vertical steering magnets follow the main D quadrupoles. Phase advance from one steering to the next is about π/2 for both horizontal and vertical.

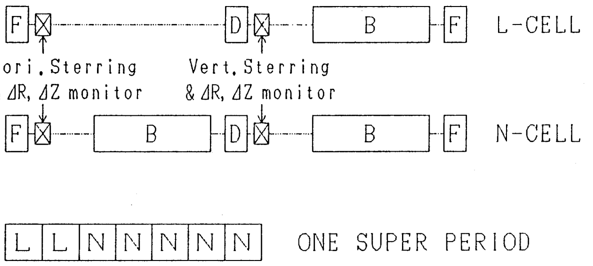

Fig.1 Main ring lattice of KEK PS and positions of steering magnets.

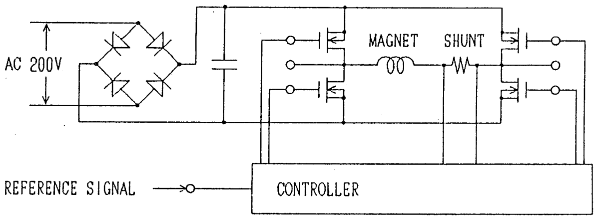

Fig.2 The circut of power supply for dynamic steering.

Power supplies

The new power supplies for this upgrade are diodes and power FET bipolar current regulated power supplies. Principle of circuit is shown in Fig.2. Their maximum current and voltage are ±6.5 A and ±75 V. This corresponds to maximum deflection angle of ± 4.3 mrad. for 500MeV proton and ±0.36 mrad. for 12GeV proton except for III-2F steering. The current setting accuracy is 1 X 10^{-3} for DC signal. Response time to the reference signal is less than 20 ms.

Power supplies are situated in 4 auxially rooms (M1 - M4) distributed around the accelerator ring. In each room 14 power supplies (7 for horizontal and the other 7 for vertical) are set in one rack as shown in Fig.3 .

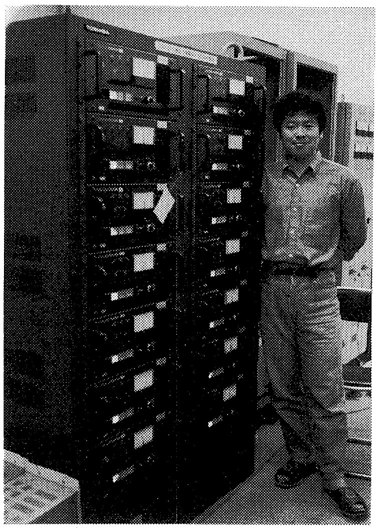

Fig.3 Power supplies of dynamic steering system. The size of one power supply is 1755(H) X 1100(W) X 800(D). 14 power supplies are set in one rack.

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Control system

Layout of the control system is shown in Fig. 4. Several microcomputers connected with VME-bus [3] control dynamic steering system. VME crates are set at 4 auxially rooms. Each crate controls have two DA boards, Digital input board and Relay board. One DA board supplies 8 channels of reference signals ; 7 channels for dynamic steering and one channel for the other purpose (excitation pattern of sextupole, etc.). Digital input board and Relay board control ON/OFF of power supplies and monitor status signals. In Central Control Room (CCR) some sets of general purpose graphic consoles are available for dynamic steering control, where we also monitor closed orbit through VME-bus.

Excitation pattern data is created at VME console in CCR and sent to VME crates in auxially rooms. Data size for 1 channel (or for 1 steering magnet) is 12 bit X 2048 steps. Each DA board in the crates memories excitation pattern data of 8 channels and output 8 analogue reference signals. The start signal and the 4kHz clock signal are sent to DA boards from CCR. The start signal reset analogue output to the first step. The clock signal advances step of 8 channels successively. Then all data covers 2 ms X 2047 steps = 4.094 sec, which is close to an acceleration cycle. The step of excitation patterns by 2 ms are smoothed through LPF, response of power supplies and magnets. When acceleration cycle is 2.4 - 2.5 sec (short flat top mode), clock frequency is set to 6.4 kHz. The resolution of 12 bit crresponds to deflection of 0.0021 mrad. at the injection. This single kick error produces Closed Orbit Distortion of 0.055 mm max for horizontal and 0.033 mm max for vertical. These are sufficiently small.

Two ways of data creation are available. One is to edit data file on hard disk and sent data to DA board. Another is to change running data with graphic display and touch panel. The latter way does not change data file but changes DA board memories.

Closed orbit control

Now we have not introduced variable γ_t yet, we control closed orbit only at the injection porch, early stage of acceleration, near the γ_t and the extraction porch. We made steering excitation pattern first with best corrector (or best steering) method and after that with local bump method. There is now no soft ware program works on VME yet which connect Closed Orbit data to steering excitation pattern. So the steering patterns are calculated with other computer than VME and are modified by human under some considerations.

Closed orbit with no steering excitation is shown in Fig. 5(a) and (b). The horizontal and the vertical betatron frequencies are 7.12 and 6.22 respectively during the acceleration. Horizontal closed orbit distortion is small at the injection (from P1 to P1+510 ms), but the closed orbit changed greatly during the acceleration. On the other hand vertical closed orbit distortion has 6th harmonics at the injection and that does not change much from injection to extraction. The source of horizontal closed orbit change is perhaps the bending magnets. Especially the change of horizontal closed orbit at the early stage of acceleration was due to the eddy current at III-2F bending magnet.

Example of controlled closed orbit is shown in Fig. 5(c) and (d). There remains distortions of about 2 mm, supposed to be the position errors of monitors. Typical excitation patterns of steering magnets are shown in Fig. 6. Excitation currents of vertical steering magnets roughly proportional to proton momentum. But that of horizontal steering magnets are more complicated because of the closed orbit change during the acceleration and of making some necessary bump orbits as shown in Fig. 5(c). Totally the closed orbit is sufficiently controlled by the present system.

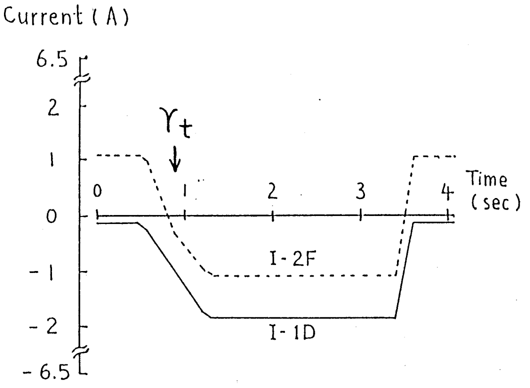

Fig.6 Example of excitation patterns of steering magnet. Solid line is the pattern of vertical steering I-1D and dotted line of horizontal steering I-2F.

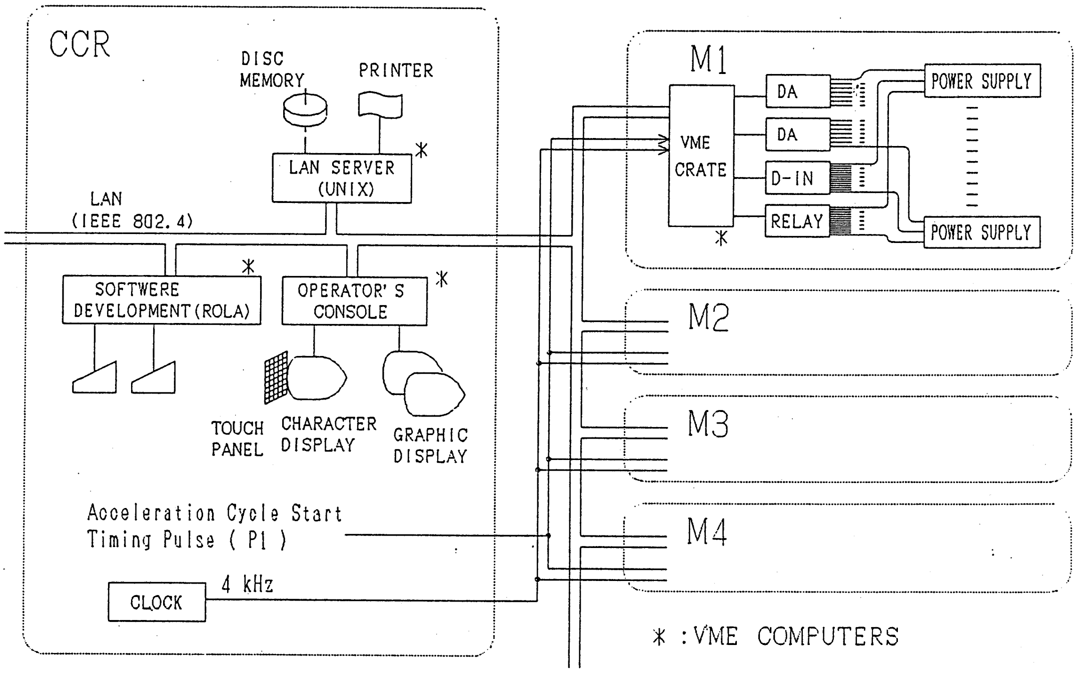

Fig.4 Control system of dynamic steerings.

Acknowledgement

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References

[1] A. Ando IEEE trans. on Nucl. Sci. vol. NS-32, N0.5, 1985.
[2] H. Sato, et al., Nucl. Instr. & Meth. A272, 1988
[3] T. Katoh, et al., Proc. of the 14th International Conference on High Energy Accelerators, August 22-26 1989, Tsukuba, Japan.

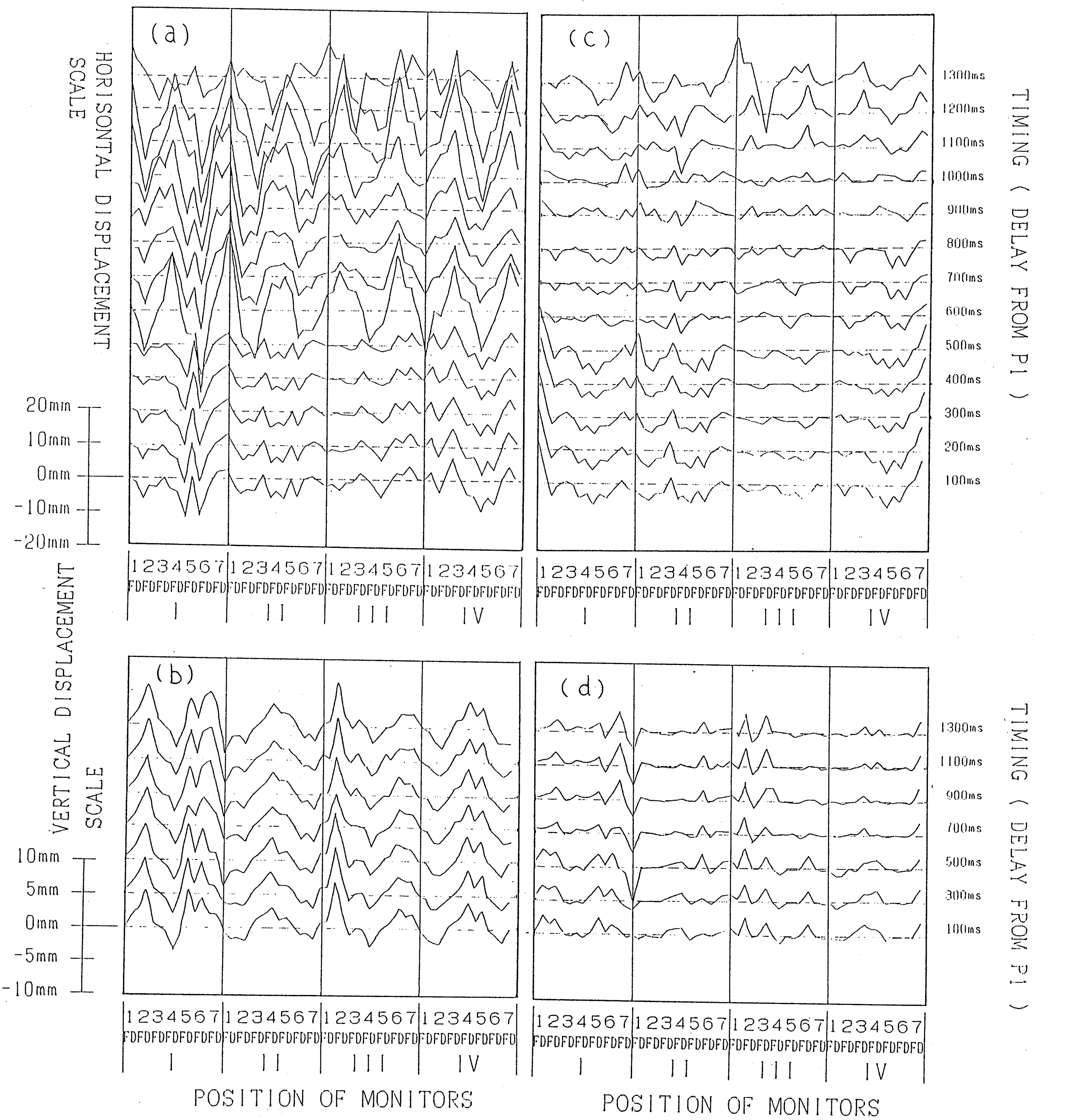

Fig.5 Horizontal(a) and vertical(b) closed orbit change without steering excitation. And horizontal(c) and vertical(d) closed orbit change under closed orbit control by the dynamic steering system. They are measured with 100 ms step for horizontal and 200 ms step for vertical. Beams are injected from start trigger timing (P1), acceleration starts at 510 ms after P1, phase transition occurs at 850 ms after P1 and reach to the flat top at 1300 ms after P1. In Fig.(c) I-1F bump at the injection (0-510 ms) is for widen the aperture of injection beam, and the bump from II-7D to III-3F at the extraction (after 1300 ms) is extraction bump made by extraction dipoles.