Slow extraction system and control at the KEK 12GeV-PS main ring

10th ICFA mini-workshop on slow extraction
October 15 - 17, 2002 at BNL

Hikaru sato, KEK

PS main ring and Power Supply group :
Hikaru Sato, Noboru Tokuda,
Masashi Shirakata, Susumu Igarashi, Katsumi Marutuka,
Tsuyoshi Sueno, Katsuhiko Mikawa

PS control group : Hidetoshi Nakagawa

Musashi Institute of Technology : Koichi Mochiki

ABSTRACT

Half-integer resonance extraction at the betatron tune of 7.5 has been utilized for the KEK 12GeV-PS main ring. There are two extracted beam lines to East counter hall (EP2-line) and North counter hall (EP1-line). For the EP1-line, both of slow and fast extraction system is installed. Extraction system, performance of technique to reduce the spill fluctuation and the spill control system, which has been upgraded by using the Digital Signal Processor (DSP), are presented. Trouble experiences in the system maintenance are also pr esented.

Historical Review of the Slow Extraction at the 12GeV-PS

Extraction system at the KEK 12GeV-PS main ring

Servo-Spill Control Analysis

Control System using Digital Signal Processor

Problems

Conclusion

References

Slow Extraction

SLOW EXTRACTION FROM KEK PS MAIN RING
K.Endo, Y.Kimura, S.Mitsunobu, S.Ninomiya, Y.Sakamoto, H.Sato, Y.Takeuchi and S.Tokumoto, IEEE Trans. on Nucl. Sci. NS26(1979)3170

EFFECT OF THE NONLINEAR FIELD ON THE SLOW EXTRACTION
S.Ninomiya, H.Ikeda, S.Mitsunobu, Y.Sakamoto, H.Sato, M.Takasaki, Y.Takeuchi, A.Yamamoto and K.Endo, Proc. of the XIth Int. Conf. on High Energy Acc., Geneva(1980)341

Some Techiniques to Improve Time Structure of Slow Extrcted Beam
Y.Shoji, H.Sato, T.Toyama, K.Marutuka, T.Sueno, K.Mikawa, S.Ninomiya and M.Yoshii
Proceedings of the 8th Symposium on Accelerator Science and Technology, Nov. 25-27, 1991, Saitama, Japan, p.329

Improvement of the Slow Extracted Beam Spill Time Structure at the KEK 12-GeV PS
H.Sato, Y.Shoji, K.Marutsuka, T.Toyama, T.Sueno and K.Mikawa
Proc. of the 15th Int. Conf. on High Energy Accelerators, July, 1992, Hamburg
Int.J.Mod.Phys.A(Proc.Suppl.)2A(1993)495

Slow Extraction System of the KEK-PS, Y.Shoji, K.Marutsuka, T.Toyama and H.Sato, KEK Report 93-10, November 1993, A

Frequecy Responce of Slow Extraction Process
T.Toyama, H.Sato, K.Marutsuka and M.Shirakata
Proceedings of the 9th Symposium on Accelerator Science and Technology, Aug. 25-27, 1993, Tsukuba, Japan, p.404

Analysis of the Servo-Spill Control for Slow Beam Extraction
H.Sato, T.Toyama, K.Marutsuka and M.Shirakata
Proceedings of the 9th Symposium on Accelerator Science and Technology, Aug. 25-27, 1993, Tsukuba, Japan, p.208

Intensity Asymmetric Multiple Slow Extraction at the KEK-PS
M.J.Shirakata, K. Marutuka, Y.Shoji and H.Sato
Proc.of the 1997 Particle Accelerator Conference, May, 1997, Vancouver, p.267

SPILL SERVO CONTROL BY DSP
H.Nakagawa, J.Kishiro, H. Sato, M.Shirakata, K.Marutsuka, H.Tanaka, K.Onoue and S.Arai
ICALEPCS 99, Oct. 4-8, 99 Trieste, P.293

Slow Extraction Control Using the Digital Feedback Systems
H.Nakagawa, H. Sato, J.Kishiro, K.Marutsuka,

M.Shirakata, H.Tanaka, K.Michiki and S.Arai
Proc.of the 2000 European Particle Accelerator Conference, 26-30 June 2000, Austria Center Vienna, p.1921

Power Supply

Repetitive Voltage Control of the Main Ring Magnet Power Supply for the KEK 12GeV PS
T.Sueno, S.Matsumoto, K.Mikawa, M.Toda, H.Sato, N.Kumagai and H.Baba
Proc. of the 14th Int. Conf. on High Energy Accelerators, August 22-26, 1989, Tsukuba, Japan, Particle Acc. 29(1990)133

Upgrade of the Main Ring Magnet Power Supply for the KEK 12GeV Proton Synchrotron
H.SATO, T.SUENO, T.TOYAMA, M.MIKAWA, M.TODA and S.MATSUMOTO
Proc.of the 1991 IEEE Particle Conference, San Francisco, May 6-9, 1989, 1991, p.908

HIGH ACCURACY MAGNET POWER SUPPLY FOR PROTON SYNCHROTRON BY REPETITIVE CONTROL
H.Sato, T.Sueno, T.Toyama, M.Mikawa, M.Toda and S.Matsumoto
PESC'91 RECORD, 22nd Annual IEEE Power Electronics Specialist's Conference, Boston, Massachusetts, June 24-28, 1991, p.812

Reduction of the Uncharacteristic Ripple Component in the Synchrotron Power Supply
H.SATO, T.SUENO, M.MIKAWA and T.TOYAMA
Conference Records of the IEEE Nuclear Science Symposium, Orlando,Florida, Oct. 1992, p.569.

Equivalent Transfer Function Generator of Magnet Power Supply Using DSP
H. Sato, T. Sueno, K. Mikawa, S. Igarashi, H. Nakagawa, K. Mochiki, H. Abasaki and S. Arai
Proc.of the 2002 European Particle Accelerator Conference, 3-7 June 2002, Paris

History of KEK Proton Synchrotron

1971	Apr.	Construction Start
1974	June	750 KeV Pre-Accelerator
	Aug.	20 MeV LINAC
	Dec.	Booster Accelerated up to 500 MeV
1975	Dec.	MR Injection
1976	Mar.	MR Accelerated up to 8 GeV (Original Design)
	July	Utility Start Using Internal Target
	Dec.	MR 12 GeV
1977	Jan.	Fast Extraction to EP1 Line
	May	Utility Start for Bubble Chamber Experiment
	June	BSTR Intensity 6 x_10^{11} ppp
	Nov.	Slow Extraction to EP2 Line and Utility Start
1978	July	MR Intensity 2 x _10^{12} ppp
1980	Jan.	MR Intensity 2.85 x 10^{12} ppp
	May	MR Intensity 4.07 x 10^{12} ppp
	June	Utility Start to Booster Facility
1981	July	Shut Down of Fast Extraction
	Dec.	MR Intensity 4.1 x 10^{12} ppp

Slow Extraction to EP2
Fast Extraction to EP1 (by fast bump magnets)

1983	Nov.	H^- Injection to Booster
		Polarized Proton Beam Acceleration Test Start
1984		Long Shut Down due to TRISTAN Construction
	May	Replace of Preaccelerator Tube
1985	Nov.	LINAC Upgrade to 40 MeV
1986	May	Pulse Sharing Operation of Normal Intensity Beam and Polarized Proton Beam
1987	May	Utility Start Using Polarized Proton Beam
1988	May	Replace of Control System from Melcom to VME
1989	June	MR Intensity 5.4 x 10^{12} ppp (max.)

Internal Polarimeter was set at the straight section of EP1

1990	May	BSTR Intensity 2.4 x 10^{12} ppp
	Aug.	MR Power Supply Upgrade for the Flat Top Extension
	Sep.	Replace of EP1, EP2 Extraction system
		Realignment of the main ring Q magnets (vertical)
	Oct.	EP2 Spill Length of 2 sec
1991	Jan.	Slow Extraction to EP1
	May	Start of Deuteron Beam Acceleration Test
1992	Jan.	Accelerated and Extracted of Deuteron Beam at 11.2GeV
	Apr.	Utility Start Using Deuteron Beam
		Variable Energy Extraction
1994	Apr.	Septum-bump injection system was developed
		Acceleration Test of _ Beam and Utility Start at 23GeV

1994 Aug. Realignment of the booster magnets

Nov. MR Intensity 5.95 x _10^{12} ppp (max.)

1995 Feb. Study for the Intensity Upgrade

1996 Mar. Polarized Duteron Beam Accelerator Test

Sep. B-Q Duct and BPM Replacement (partially)

Realignment of the main ring Q magnets (vertical, partially)

Oct. MR Intensity 5.5-6.1 x 10^{12} ppp (20 min. AV)

1997 Upgrade of the Pulsed Quarupole Power Supply for the Transition Crossing

Studies for the Beam Loss at the Acceleration Start

Fast Kicker Magnets Design and Construction

Slow Extraction to EP2

Slow Extraction to EP1

1998 June MR Intensity 4.7-4.9 x _10^{12} ppp during utility run

Half Year Shut Down for the Preparation of the Long Base Line Nuetrino Experiment

Installation of the Fact Kicker Magnets

Replace of the Septum Magnets Power Supply

1999 Feb. Fast Extracted Beam to the Production Target Position

Mar. Comissioning start of the Long Base Line Nuetrino Experiment

May MR Intensity 6.2 x 10^{12} ppp

June MR Intensity 6.8 x 10^{12} ppp

2000 Mar. MR Intensity 8.0 x 10^{12} ppp

Slow Extraction to EP2

Slow/Fast Extraction (by kicker magnets) to EP1

Acceptance of the Main Ring
(mm . mrad)

	Design (assumed COD 12.3mm) (KEK-74-4)	Calculated from (aperture and real COD) (ASN-346)	Measured (by small emittance beam) (KEK Internal 95-12)	Meas (by meth (KEI nal 12
A_H	81.5	135.0	81.0	88
A_V	19.6	31.0	15.0	

Half Integer Resonance Extraction

Magnetic field : Just after reaching flat top

Operating point : ν_H 7.15--> 7.4 within 100ms
by Focusing Q mag.

Current Ripple : 2×10^{-4} - 5×10^{-5} at Flat Top

Extraction Q mag. ---> Stop Band
Spill Servo Control
(DC – 100Hz)

8 pole magnets : Turn Separation

6 pole magnets : Chromaticity

Ripple correction Q mag. : 100 - 1kHz ripple

ESS : 0.1mm W wire DC100kV/cm
(Leak current problem)

Septum Magnets (Mechanical damage)

Bump Magnets

Debunching of RF : Micro Structure

Simultanuous Extraction to EP1 and EP2

(Large beam loss at the extraction)

Status of the 12 GeV-PS and Utilities

Repetition 2.2 - 4 sec.
Flat Top .2 - 2 sec.
Energy 1 - 12 GeV (for Proton)
9 Pulses Injection from 500 MeV Booster

Fast/Slow Extraction to EP1
Slow Extraction to EP2

Long-Baseline Neutrino Experiment
High Energy Physics,
Meson Spectroscopy, Hypernuclei,
Multi-Fragmentation,
(Spin-Spin Interaction)

Secondary Beam from the Internal Target to
East Counter Hall

Dedicated to detector check for
CDF, RHIC-PHENIX,KEK-B, etc.

Conclusion - *PS Upgrade*

Past

- Flat Top Length 0.6 sec
  1.8 sec
- Variable Energy
- Multi-Function Machine
- Septum-Bump Injection Magnet
- Polarized Ion Source & Polarized Proton Beam (p/d) and α Beam Acceleration
- B - Q duct Replacement
- BPM Upgrade
- h = 6 RF Operation

Present

- Fast Extraction for the Long Base Line Neutrino Oscillation Experiment
- DSP Servo-Spill Control
- MA cavity study for JKJ

Future Study for the Induction Accelerator (? Shut down at 2004 ?)

Fast extraction of 12GeV Protons

Motivation : Long baseline experiment with neutrino beam.

Neutrino Beam Produced
by Fast Extracted High Intensity Proton Beam

from KEK-PS to Super- Kamiokande.

E362 :
(K2K : KEK to Kamioka)

Request : 10^{20} protons for 500 events.

Moderate intensity : 4 x 10^{12} ppp /
2 p/sec x 10^{7} sec = **2 x 10^{19}**

Need 5 years !! or more higher intesity beam.

56 events at this present for past two years.

Experiment will start from coming December.

Stabilization and Ripple compensation of the main ring power supply

for AC line: Harmonic filter
Reactive power compensator

for DC line: AVR
ACR
Repetitive Control of Current Deviation
APPS tuning
DC low pass filter
DC active filter

Very high accuracy tracking and stability (10^{-4}) was achieved using several control systems complex, especially using a repetitive control method, in spite of pulse operating high power supply with high inductance load. Ripple is reduced by filter systems and APPS tuning. (10^{-5} - 10^{-6})

The ripple are reduced well by the W.F.Prage type passive low pass and the active dyn amic filters

The parasitic ripples except logical component are generated by symmetry breaking among the ignition timing of SCR on multi-phase ac lines, by steady distortions of line voltage, or by noises including common mode. The main part of 100Hz ripple has been derived by voltage imbalance of a single phase among three phases on the ac power line, but the major of the part has been cancelled out by the voltage imbalance control in the reactive power compensator and APPS.

Disturbance from AC commercial line due to the electronic furnace.

Problems

Large beam loss at the extraction.

No study time due to main dedication for K2K Experiment and short time for slow extraction.

Deterioration of almost equipments.

Work at the high radiation area.

Reduce the running budget and man-power since PS will be shut down at 2004 fiscal year.

50GeV at the JKJ project will be commissioned two or three years after PS shut down.