IMPROVEMENT OF THE CONTROL SYSTEM FOR THE KEK 40-MEV PROTON LINAC

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Abstract

In order to accelerate a high-intensity beam with a good quality and to supply the beam into the 500 MeV booster synchrotron, we have used programmable logic controllers (PLC) for all control systems and introduced INTERNET technology to watch beam properties and many pulsed signals from the rf-sources. Recently, we have used a PC-based measurement system, the WE7000 series, that was developed by Yokogawa Electric Corporation, simultaneously to observe the accelerated beam characteristics and many pulsed parameters and to control the pulsed equipment.

In this report, we present the new control system and its applied results. Particularly, the relations between the beam orbits and the rf-parameters and the control method of the debuncher system are described.

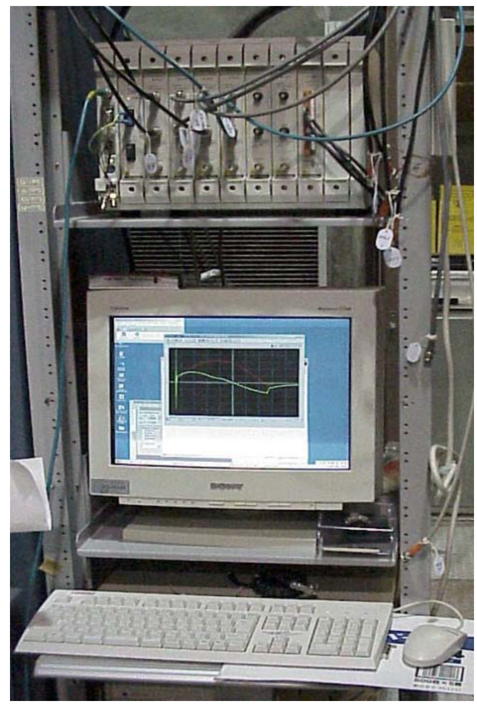
1 INTRODUCTION

To increase the beam intensity of the KEK 12-GeV Proton Synchrotron, which is composed of the 750-keV preinjector, the 40-MeV linac, the 500-MeV booster synchrotron and the 12-GeV synchrotron, for neutrino oscillation experiments, various improvements have been carried out. In particular, it is required for the linac to stabilize the centre energy and the momentum spread and then the orbits of the accelerated beam during a long operation period (about 6 months). Hence, instead of an INTERNET system to watch the pulsed patterns, we decided to introduce a PC-based measurement system (WE7000 series) simultaneously to measure many pulsed signals and to control the rf-sources.

2 COMPOSITION OF THE PC-BASED MEASUREMENT SYSTEM

The PC-Based measurement system selected as a precise data acquisition instrument at the KEK PS linac is the "WE7000 series", mainly because of easy configuration and Windows-based control modules. Picture 1 shows the composition of " WE7000 " and a personal computer.

Our "WE7000" is composed of a measuring station with 8 slots for measurement modules and 1 slot for a communication module, an optical interface module, 2-ch 1 MS/s isolated digitizer modules and a 4-ch 100 kS/s isolated D/A module. The optical interface module and isolated modules are selected to provide a noise-immune link to the PC and many apparatus. A trigger and a timing signal are available in order to synchronize multiple modules, as shown in the Fig.1. Hence, it is very easy to simultaneously measure many pulsed signals generated from beam monitors and rf-monitors. Visual Basic software and the WE7000 control software for data communication functions are used to set-up and control this system.



Picture 1: Composition of Data-acquisition system
This system is composed of a "WE7000" and a "DELL" computer

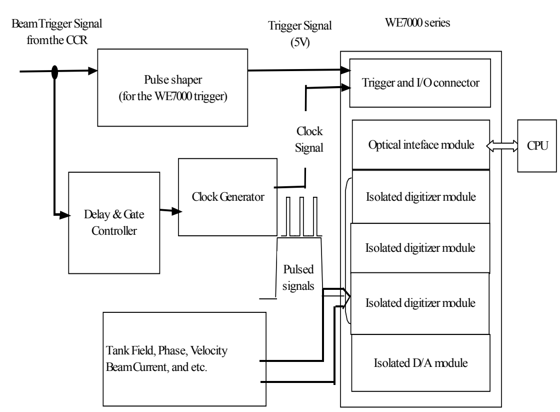


Fig. 1: Timing chart.
This system is assembled so as synchronize multiple modules and to save the storage files.

3 APPLICATION OF THE PC-BASED MEASUREMENT SYSTEM

By introducing PC-based measurement instruments, we can monitor the relation between the rf-parameters and the beam position and stabilize the debuncher system. Particularly, stabilization of the beam orbit and accelerated energy is required in order to accelerate a high-intensity beam at the KEK 12-GeV PS.

Fig.2 shows the KEK 40-MeV proton linac, the 40-MeV beam lines and monitors installed on this line.

3.1 Stabilization of the debuncher system

We tried to stabilize the beam energy by using some velocity monitors. [1] An analogue feedback circuit and a PLC were used to control a phase shifter. As an experimental result, we have proved that using the velocity monitor is effective for stabilizing the beam energy. [2] Hence, we have applied the PC-based measurement system to control the phase between the debuncher cavity and an rf-source.

At first, we investigated the relation between the accelerating energy and the phase of the debuncher cavity with beam energies injected into the debuncher. The variation of the injection energies was carried out by changing the tank rf-levels and the phase between two tanks. With these procedures, correlations between the accelerated beam energy and the rf-levels (or phases) were measured. We then also reconstruct the experimental formula in order to maintain constant phase between the beam signal and the debuncher cavity, while considering change of the phase due to a variation of the beam velocity through the drift space and due to the synchrotron motion in the tank. This formula is a function of the rf-levels, the phase between two tanks and the beam velocity. After many parameters were measured, the feedback was calculated by this experimental formula. Then, the phase shifter was controlled with the appropriated amount of feedback. Fig.3 shows the results measured under some conditions of the feedback system when the phase between two tanks changed.

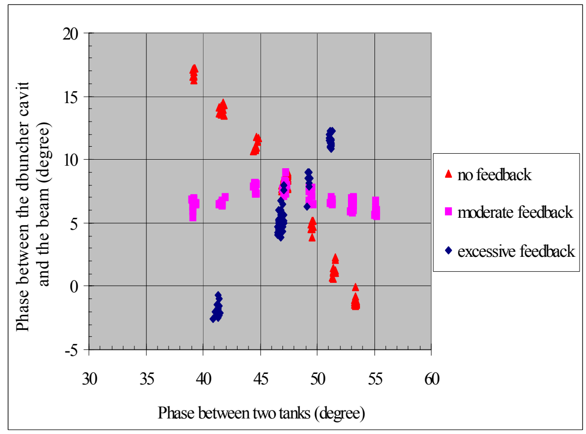


Fig. 3: Effect of the feedback
The feedback quantity is determined by the experimental formula. This formula is produced by analysing the stored data.

In Fig.3, the variation of the measured points is due to noise from the phase detector used and the monitor head.

We think that it is possible to maintain a constant phase between the beam signal and the debuncher cavity and to stabilize the accelerated energy by using the PC-based measurement system.

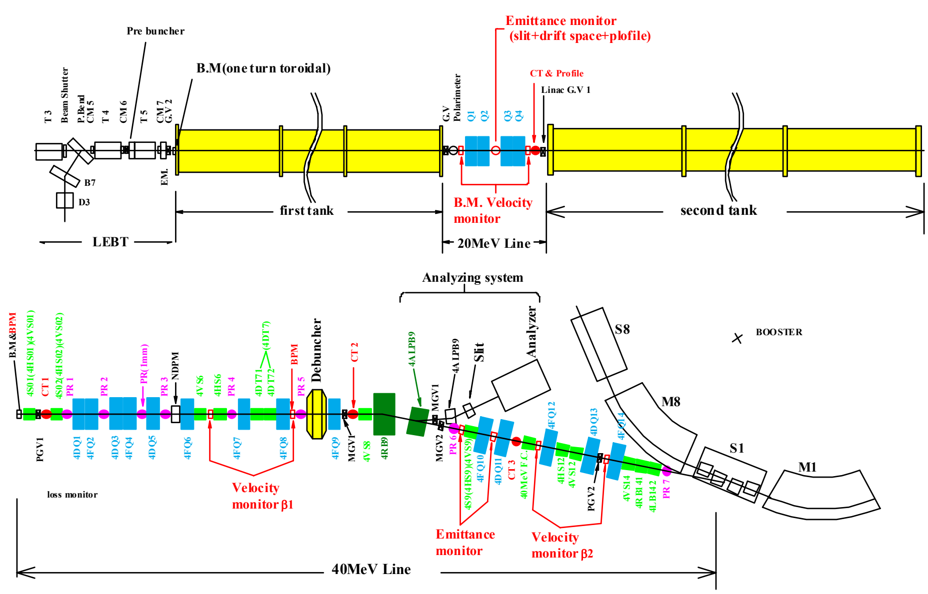


Fig.2: KEK PS-40 MeV proton linac and the 40 MeV beam line
On this beam line, two velocity monitors (β1,β2), BPM's, profile monitors and the emittance monitor are installed.

3.2 Data treatment of a beam-position monitor

In general, any misalignment of the drift tubes and the injection errors to the linac made the beam orbit deformed. This orbit deformation causes a dispersion term to be generated. Hence, the variation of the longitudinal parameters (rf-field levels, phase between tanks etc.) affects the beam orbit and then complicates any non-linear effects due to the non-linear elements.

Miller et al. proposed the use of BPMs as non-intercepting emittance monitors. [3] Furthermore, for the JAERI/KEK joint project, [4] it will be a necessary to monitor and correct any orbit deformation and an rms emittance blow-up in a non-destructive way.

As seen in Fig.2, many beam position monitors (BPM) are installed on the 40-MeV beam line. The BPMs consist of four pickup buttons with an angle of 90 degrees. The output signals of the four buttons are connected to a 201 MHz band pass filter, amplified and then sent to the PC-based measurement instrument, where the quadrupole term and the beam position in the horizontal and vertical planes are provided. Here, the quadrupole term is proportional to $[\sigma x^2 - \sigma y^2 + X0^2 - Y0^2]/R^2$, where σx and σy are the rms beam sizes, X0 and Y0 are the beam offsets and R is the distance of the BPM's head from the centre of the beam pipe.

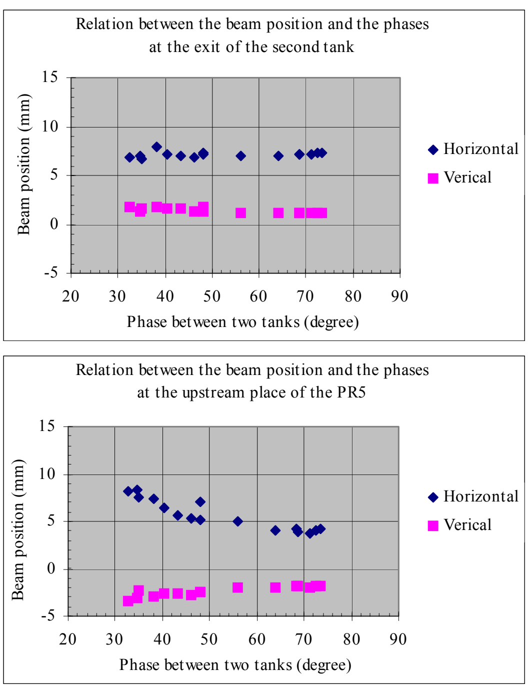


Fig4: Effect of the phase between two tanks on the beam orbit.

The measurement was carried out under the condition that variation of rf-field levels was less than 1%

We measured the relation between the beam orbit and the longitudinal parameters as well as the rms beam size by using the PC-based measurement system. Fig.4 shows the typical result measured under the condition that the variation of the rf-field levels is less than 1%. As seen in the Fig.4, changes of the phase between two tanks affects the beam orbit, particularly in the vicinity of the boundary of the acceptable phase region.

As for the quadrupole term, a calibration was carried out by comparing results observed by the BPM, which is installed in the neighbourhood of the PR5, with these estimated using data of the PR5. As a result of calibration, we proved that it is effective to use data measured in the vicinity of the centre of the beam pipe. Fig.5 shows typical example of $[\sigma x^2 - \sigma y^2]/R^2$ estimated by data of BPMs.

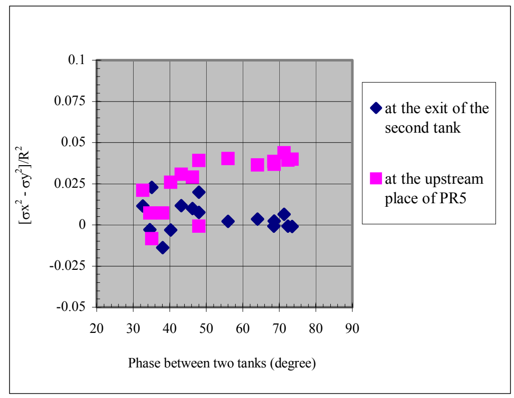


Fig.5: $[\sigma x^2 - \sigma y^2]/R^2$

This is estimated by the quadrupole term and beam offsets measured with the BPMs at the exit of the second tank and near the PR5

As seen in Fig.5, the estimated behaviour of $[\sigma x^2 - \sigma y^2]/R^2$ estimated can be unusual in the vicinity of the boundary of the acceptable phase region (from 30 to 50 degree). We can not satisfactorily understand what causes such behaviour. However it is obvious that the above mentioned phase region is inadequate for the linac operation point.

We conclude that the PC-based measurement system is very available for monitoring and adjusting many parameters for linac operation during a long operation time.

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