THE BEAM ENERGY FEEDBACK SYSTEM IN BEIJING ELECTRON POSITRON COLLIDER II LINEAR ACCELERATOR

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Abstract

The beam energy feedback system in Beijing electron positron collider II (BEPCII) linear accelerator consists of three parts. They are the beam energy measurement Input/Output Controller (BEM IOC), the Graphical User Interface (GUI) based on Qt platform and the phasing system. This article describes the implementation of this system and the online testing which has been passed on March 16th, 2016. By using this feedback system, the injection rate and the energy fluctuation of the injection beam has been improved a lot. Now this system is steady running in the control room of BEPCII linear accelerator.

INTRODUCTION

Beijing electron positron collider has been upgraded into Beijing electron positron collider II. Its storage ring has the higher demand on the quality of the beam at the exit of the linear accelerator [1]. While in the long time operation of the linear accelerator, the drift of the centre energy cannot be avoided. When the beam energy is out of the range, the injection rate will drop rapidly. To suppress the fluctuation of the beam energy at the exit of the linear accelerator and make the whole accelerator run stably, a beam energy feedback system has been developed. This system compensates the drift of the beam energy by making a local adjustment of the energy gain.

To realize the function of beam energy feedback, we first set up a kind of online beam energy measurement mechanism at the exit of the linear accelerator [2]. Then the measurement results together with the target values are sent to calculate the controlled quantity. By using the controlled quantity as the input of the actuator, the beam energy can then be adjusted. Because the klystron is working on the saturation condition, its variation of output power resulted from the variation of driving voltage is very small. To change the energy gain, the only thing we should do is to adjust the accelerating phase of klystron. Therefore, we choose the accelerating phase of klystron K16, the last klystron at the end of the linear accelerator, as the controlled quantity.

COMPOSITION

The schematic diagram of the beam energy feedback system in BEPCII is shown in Fig. 1. This system consists of three parts. They are the IOC controller for beam energy measurement (BEM), the GUI application and the phasing system.

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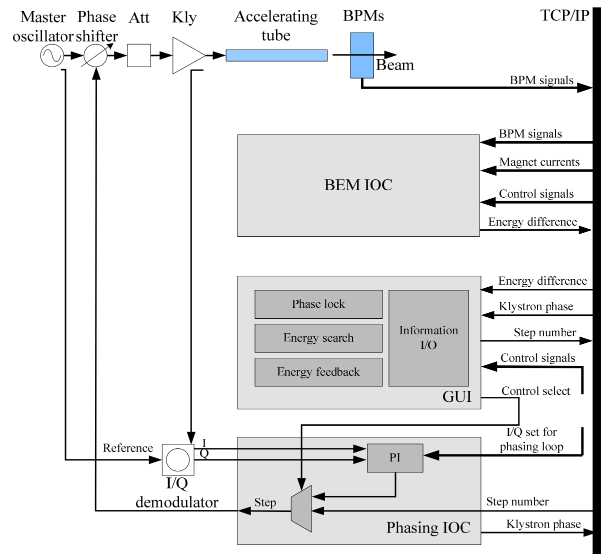

Figure 1: The schematic diagram of the beam energy feedback system in BEPCII LINAC.

The BEM IOC

The BEM IOC uses a kind of online beam energy measurement method. During the injection, the IOC acquires the data from the relevant channels of the EPICS [3], calculates the difference between the actual energy and the nominal energy by using certain programs, and sends the difference to the Ethernet via EPICS channels. The GUI application can then utilize the data come from the local area network.

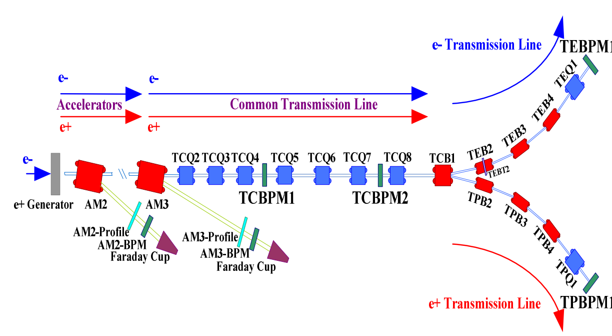

Figure 2: The layout diagram of the BPMs and the magnets at the end of BEPCII LINAC.

The data acquired by the BEM IOC are mainly the beam positions measured by TCBPM1, TCBPM2, TE/PBPM1 and the magnet currents between them (the positions of the BPMs and the magnets are shown in

Fig. 2). We use three BPMs along with the beam orbit to measure the difference between the real beam energy and the nominal energy. The first two BPMs are in the straight section and their task is to detect the beam orbit. The third one is in the big dispersion place of the transmission line following the bending magnets and is the key point to calculate the energy difference. Because this method takes the effect of orbit fluctuation into account, the measurement result is much accurate than the one using the single BPM. There are two groups of BPMs in the big dispersion place that can be used to do the energy measurement. They are TE/PBPM1 and TE/PBPM3. When we used the correlation test to make sure the reliability of their measurement results, we found that the displacement of the beam centre measured by TE/PBPM3 became smaller instead of bigger as the beam orbit had a larger offset. Along with the phenomenon, there was an abnormal decrease of the ADC converting signals [4]. So we finally selected TE/PBPM1 as the energy measurement BPMs considering the data reliability and the error accumulation. What's more, the ADC converting signals of these BPMs are obtained by the BEM IOC to exclude the abnormal signals and prevent the energy measurement from the disturbance.

The maximum beam repetition of BEPCII linear accelerator is 50 Hz. However, due to the limitations of the Windows platform and the EPICS, the time delay for data acquisition is between 1ms and 100ms. Hence, the data sampling rate of the BEM IOC is set to be 10 Hz. In the above case, it is not a pulse-to-pulse system, but considering that the phasing system is the combination of stepping motors and phase shifters, which belongs to the slow adjustment system, this kind of energy measurement meets the requirements of phase adjustment and energy fluctuation suppression.

The GUI application

The GUI application has two significant functions. First is to communicate with the users, including the information input and the result exhibition. Second is to obtain the data from relevant channels, calculate the controlled quantity and send it to EPICS channel to control the accelerating phase, which can then change the beam energy.

Because of the communication function, the application is set to be easy to use and its interface is also very visual (its language is Chinese for its users are all from China). We use Qt [5] as the development platform of the application for the following reasons: 1. The GUI of the phasing system, which has worked in the control room for nearly 10 years, is developed by using Qt platform. Practice has proved that this platform is compatible with Windows operation system very well; 2. After compiling and synthesizing the code written in this platform, we may obtain an executable program with the suffix of ".exe". The operators can open it rather easily by double clicking it; 3. This platform uses C++ as the programming language and there are many plug-ins supporting it. For example, a plug-in called Qwt [6] allows the application to plot easily; 4. This platform has an open source version.

The GUI application runs the phase locking algorithm, energy searching algorithm and energy feedback algorithm in background. Each time the application finishes the phase adjustment, it will keep the phase in a certain value by activating a phase close loop. The energy searching algorithm works when the output power of klystron has a large variation and there is no beam going through the transmission line. The search range is from 0 degree to 90 degree of the accelerating phase. If the BEM IOC detects that there is beam going thought the transmission line, the energy searching will be stopped and the energy feedback function will be activated. If the IOC doesn't detect the beam going through the transmission line in the search range, the control of the application will be forbidden and a warning window will popup. We used the step number instead of the speed of the stepping motor as the controlled quantity, because the Ethernet will be disconnected sometimes in the situation of strong electromagnetic fields, and the step number mode can prevent the motor from being out of control. Both the phase locking algorithm and the energy feedback algorithm take the return difference of the phase shifter into account when they control the step motor.

The phasing system

The beam energy feedback system adjusts the accelerating phase by using the phasing system [7], which has worked in the linear accelerator for nearly ten years. What we have done for the phasing system is to improve it to make it meet the needs of the feedback system. The first one is about the speed of the motor. Because we choose step number as the controlled quantity, its speed should be set as a constant. There are two kinds of speed used here. The slow one is for manual operation and the fast one is for automatic operation. The second is about the priority of the control of the phase. The energy feedback system has the higher priority, when it works, the phase control application in control room is forbidden.

PERFORMANCE OF THE SYSTEM

The beam energy feedback system passed the online testing on March 16, 2016. Its performance is shown in Fig. 3. The left half graph is the record of the injection data when the energy feedback system is on, and the right one is the record when the system is off. According to the record, there is an effective suppression to both the fluctuation of the beam energy and the injection rate when the feedback system is on. By using the energy feedback system, the peak to peak value of the injection rate is less than 10 mA/min. While without the system, this value is larger than 20 mA/min.

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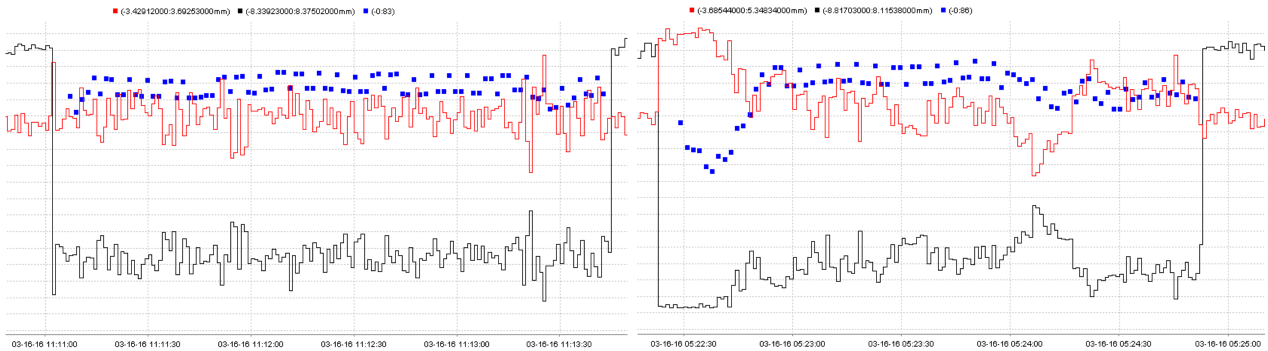

Figure 3: The comparison of the injection with the beam energy feedback system on (left) and the injection with the beam energy feedback system off (right). The blue points are the injection rate values recorded by Archive Database. The red line is the measurement result of TPBPM1 and the black line is the measurement result of TPBPM3. They indicate the fluctuation of the beam energy to some extent.

After online testing, the beam energy feedback system is put into operation. And now it has adapted to different operational modes of the injector, such as the electron injection for collision mode, the positron injection for collision mode and the electron injection for synchrotron radiation mode.

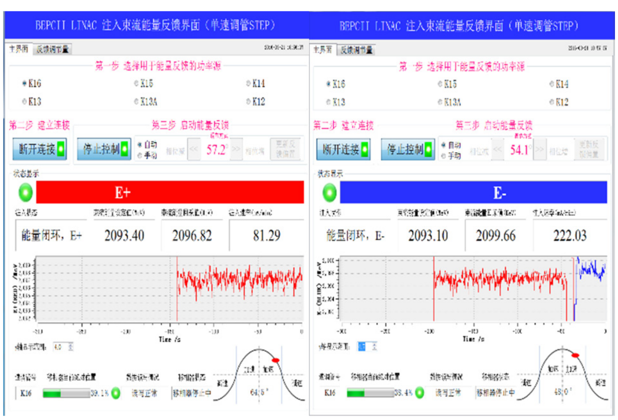

Figure 4: The screenshot of the system in collision mode (left is for positron injection and right is for electron injection).

Figure 5: The screenshot of the system in synchrotron radiation mode (top-up injection mode).

Figure 4 is the screenshot of the working condition of the system in collision mode (left is for positron injection and right is for electron injection). For positron injection, the target energy is 2096.1 MeV and the mean value of the actual energy is 2096.2 MeV. Meanwhile, its standard deviation is 0.8 MeV and peak to peak value is 4 MeV. The energy fluctuation is 0.95‰, which meets the design requirement of 1‰. For electron injection, the target energy is 2098.2 MeV and its mean value of the actual energy is 2098.2 MeV. Its standard deviation is 0.7 MeV and peak to peak value is 3 MeV. The energy fluctuation is 0.72‰, which meets the design requirement of 1‰. Figure 5 is the screenshot of the working condition of the system in synchrotron radiation mode.

SUMMARY

The beam energy feedback system for Beijing electron positron collider II linear accelerator has been developed successfully. It consists of the BEM IOC, the GUI application and the phasing system. The three parts of the system communicate with each other through the Ethernet, and work together to realize the energy adjustment of the injection beam. Now this system is running stably in the control room and has adapted multiple injection modes. It can eliminate the low point of the injection rate caused by the fluctuation of the beam energy effectively and has a significant contribution to increase the average rate of injection.

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