IMPLEMENTATION OF SINAP TIMING SYSTEM IN SHANGHAI PROTON THERAPY PROJECT

B. Q. Zhao*, L. Y. Zhao, M. Liu, C. X. Yin, SINAP, Shanghai, China

Abstract

SINAP v2 timing system was implemented in the timing system of Shanghai Proton Therapy Project. The timing system in Shanghai Proton Therapy Project is required not only to generate operation sequence for medical proton synchrotron, but also to realize irradiation flow for beam delivery system. For these purposes, the firmware of SINAP v2 timing system is redesigned to satisfy both event code sequenced broadcasting to generate operation sequence and bidirectional event code transmit to realize irradiation flow. Thanks of the hardware advantage of SINAP v2 timing system, the event receiver (EVR) could transmit event code to event generator (EVG) and then broadcast to timing network. By this design, the EVR installed in treatment room has ability to send event code to timing network to stop/start beam during slow extraction. The architecture of the timing system in Shanghai Proton Therapy Project is presented in the paper. The hardware and event codes design are also discussed in detail.
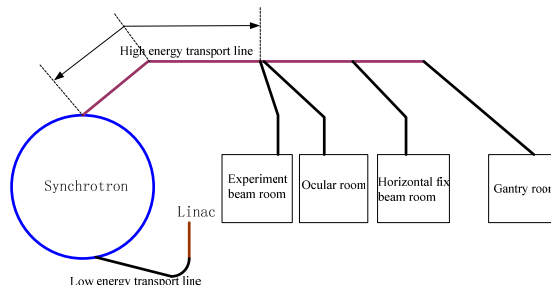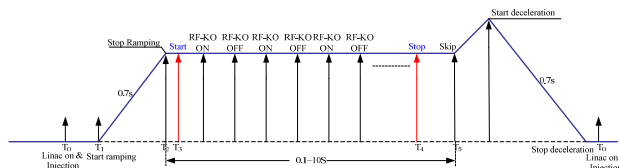
INTRODUCTION

Shanghai Proton Therapy Facility consists of a 7 MeV Linac, a 70 MeV to 250 MeV synchrotron and beam switchyard, which is scheduled for commissioning in 2018.

SINAP v2 timing system is implemented in the timing system of Shanghai Proton Therapy project, which is operated at Shanghai Synchrotron Radiation Facility (SSRF)[1] for almost 4 years. The high stability performance of SINAP v2 timing system at SSRF guarantees its medical implementation in Shanghai Proton Therapy project.

SYSTEM OVERVIEW

The whole facility scheme is shown in Fig. 1. Firstly, the protons that are produced by ion source are accelerated to 7MeV through 4.5 meters of Linac, then injected into synchrotron. The second stage is that the energy of proton beam in synchrotron is ramped to the required energy, from 70MeV to 235MeV. Thirdly, protons are extracted to beam delivery system by RFKO slow extraction. During slow extraction duration, the beam is turned on/off by the beam delivery system, to realize spot scanning irradiation. The basic operation sequence of timing system is illustrated in Fig. 2.

T_0 is the point of protons injection; T_1 is the start point of ramping cycle; T_2 is the stop point of ramping; T_3 is the start point of irradiation; T_4 is the end point of irradiation;

Figure 1: Scheme of whole facility.

Figure 2: The basic sequence of timing system.

T_5 is the following ramping cycle point.

SYSTEM DESIGN

The SINAP v2 timing system[2] is updated to be suitable for our medical requirements. In SINAP v2 timing system, the bidirectional data transfer and EVG cascaded function have been realized in the same fibre networks. The SINAP v2 system structure is shown in Fig. 3.

The timing system of proton therapy project requires critical latency, and the parameters need to be updated cycle-by-cycle. For this purpose, EVO/EVG is installed in VME/VX Works platform to satisfy the real-time performance. And all EVR are stand alone modules. Furthermore, the EVR is installed in the therapy control system of each treatment room, which can receive event code from EVG and send event code to EVG to turn on/off beam. The hardware diagram of timing system in Shanghai Proton Therapy Project is shown in Fig. 4.

There are one EVG module and three FOUT modules in VME chassis, which is placed in RF station. In three FOUT modules, one FOUT is used to broadcast event code to EVR, and other two FOUT are used to transmit/receive event code from/to the EVR installed in each treatment room. The design of these two FOUT are for redundant purpose, and treatment switching is also realized by these two FOUT.
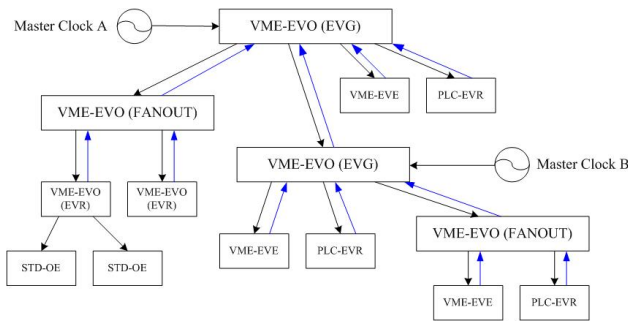
Figure 3: Structure of SINAP v2 timing system.

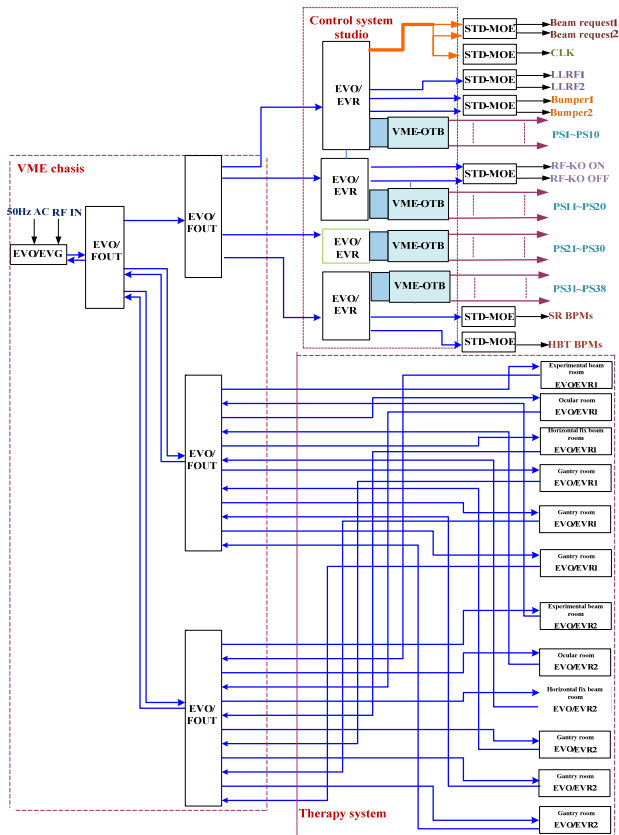Figure 4: Diagram of timing system in Shanghai Proton Therapy Project.

Figure 5: Hardware of timing system in Shanghai Proton Therapy Project.

Hardware

The hardware of this timing system consists mainly of VME-EVO, STD-EVO and STD-MOE, which are shown in Fig. 5.

STD-EVO and STD-MOE modules are standalone 1U chassis. STD-EVO also contains optic outputs (HFBR 1528) in rear panel, which could link to power supply controller. VME-EVO is standard 6U VME modules.

Event Codes Design

The timing sequence is realized by the Sequence RAM in EVG, which can broadcast event code by the defined sequence. Unlike normal event timing system, the Sequence RAM in EVG should be separated into two Sequence RAMs to satisfy the operation sequence. During these two Sequence RAMs, EVG only receive and re-broadcast event code from the EVR in treatment room.

The details of event code definition are shown in Table 1. Event code 0x1 is for proton injection, and event code 0x2 is used to stop proton energy ramping. Event code 0x3 is the start point of slow extraction, and event code 0x6 is the end point of slow extraction. Event code 0x4 and 0x5 are used to turn on/off beam during irradiation, which is generated by EVR in treatment room. Event code 0x7 is used to start proton energy damping cycle.

Table 1: Event Codes and Events

event code	event list
0x1	Injection
0x2	Stop energy ramping
0x3	Start extraction
0x4	RF-KO trigger signal
0x5	RF-KO enable signal
0x6	Stop extraction
0x7	Start energy damping cycle
⋮	⋮

Treatment Switching

The treatment switching is managed directly by the MPS system. For the treatment safety consideration, the signal between MPS system and timing system must be hardwired, i.e. the MPS transmits the hardware signal directly to the rear transfer panel of FOUT, which is shown in Fig. 6. Since the hardware signal has been divided into three-way, there could be 8 mode switches with digital coding. Moreover, timing system automatically switches to the corresponding treatment

mode, which is based on the hardware signal from the MPS.

In our design, the hardware signal that connected to the rear panel of EVG is firstly decoded and then converted into treatment signal. When the EVG receives the signal, it downloads the sequence according to energy signal delivered by the control system of treatment room.
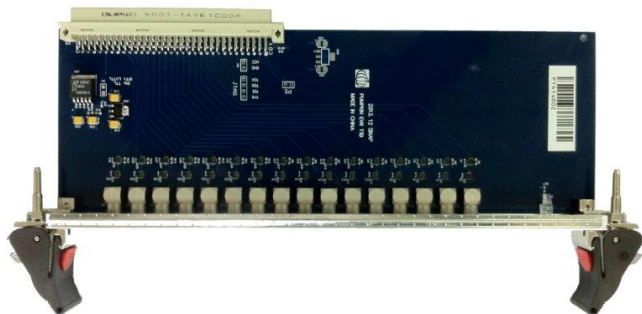

Figure 6: The rear transfer panel.

CONCLUSION

The design of timing system in Shanghai Proton Therapy Project has been completed. With the successful development of SINAP v2 timing system, the experience can be implemented in this design. In the future, all the hardware will be produced by the middle of 2016.

ACKNOWLEDGMENT

REFERENCES

[1] L. Y. Zhao, C. X. Yin, D. K. Liu et al., *Proc. of EPAC'08* (June 2008), paper THPC162, pp. 3369-3371.

[2] M. Liu, C. X. Yin, L. Y. Zhao et al., *Proc. of IPAC'13* (May 2013), paper WEPME032, pp. 2992-2994.