REJUVENATION OF LINAC CONTROL SYSTEM FOR TLS

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Abstract

The pre-injector control system is a turn-key system, which was deployed 15 years ago. It is complicated and out-of-date nowadays in terms of system integration and hardware upgrading. It must be modernized to ensure its performance and reliability, and most importantly, to facilitate system maintenance. Modernization involves upgrading to enhance functionality, to prevent obsolesce of out-of-date control modules, and to replace old parts. The purpose of the upgrade plan is to replace the pre-injector control system by a new unit which has the same control environment as that of the main control system of the NSRRC accelerator facilities. Thus, the control system maintenance, as a whole, will be made substantially easier than the original system.

INTRODUCTION

The pre-injector of the Taiwan Light Source (TLS) comprises a 140 kV thermionic electron gun and a 50 MeV traveling wave type linear accelerator (linac). The functional block diagram and layout of the pre-injector is depicted in figure-1. The electron beam emitted from the gun is accelerated through the linac with exiting energy of 50 MeV. Then, the electron beam is guided along the linac to booster (LTB) transfer line and is injected into the booster. Brief descriptions on elements in the LTB are also given in figure-1.

The control of the linac uses a dedicated programmable logic controller (PLC) equipped with 10 MB/sec Ethernet interface. It has been operated since 1990. Besides, the vacuum interlock logic of the booster is implemented using the PLC unit and is tightly coupled with the pre-injector control system. This integral arrangement causes difficulty in carrying out maintenance and replacement of some out-of-date devices in the pre-injector system. Consequently, the control system is being rejuvenated to improve its performance in the following aspects: decouple the vacuum interlock logic from the linac control system, provide better control functionality for top-up operation, and avoid lacking of out-of-date spare units. In order to achieve this goal, one VME crate system is dedicated to linac control. A new hardware unit with a high-resolution analog interface is installed to provide dedicated service of control tasks. Two separated PLCs are newly implemented to replace the "old" PLC. A compact PLC is used to deal with the interlock logic. The other PLC is used to be responsible for the remaining linac devices which require sequential control in routine operation. It includes: access interlock of high voltage (HV) and safety doors, delay process of klystron and electron gun warm-up etc. Both interlock and sequence control PLCs are controlled by using the VME crate. All other functions, without interlock or sequential requirement, are directly controlled by the VME crate. The upgrading linac control system is expected to provide better performance on control functionality and maintenance simplification.

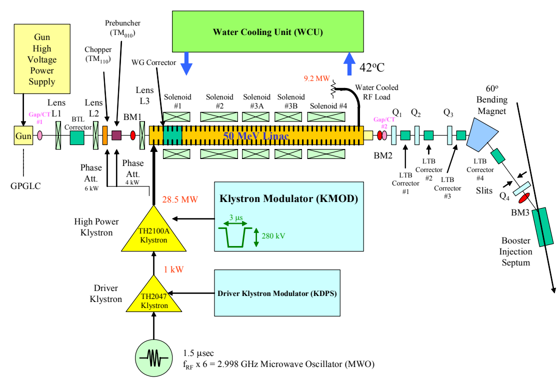

Figure 1. Synopsis of preinjector.

EVOLUTION OF THE LINAC CONTROL SYSTEM

The linac control system was embedded in the originally delivered turnkey control system of the injector, i.e. including pre-injector and booster. This system has been partly integrated with the NSRRC main control system in 1998 to enhance the operation efficiency. It reduced the resources of requirement in operating the injector and was directly benefited to performing the top-up operation. The remaining out-of-date PLC module has to be taken care of such that lacking of spare units would not jeopardize linac operation. Since top-up operation has been implemented in NSRRC in 2005, the accessible time for linac control upgrading is limited. Therefore, a long-lead transformation process toward a new control system is not avoidable. In dealing with this situation, a sideline in preparing the migration of the control environment has been exercised since July 2006 and its status is described in this report. It will become a new control system and is expected to be completed in June 2007.

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Original Turnkey Control System

The original delivered injector control system was a turnkey design and was separated from the storage ring control system. Installing and replacing new devices as needed was not a straight forward task. The hierarchy of the system had three layers, as shown in figure-2. The first layer was a VAX/VMS workstation which was employed to provide an operational interface, such as system supervision, alarm management, communication with the computers in the second layer, and creation and maintenance of the system database.

The second layer was a PC which runs an iRMX-III operation system. It served as a master in the BITBUS network in communicating with the Siemens S5/135 PLC system, and processing the data.

The third layer had two subsystems: BITBUS network and PLC system. The BITBUS system connected all devices of the booster. The linac control function was attached to the PLC which also performed the vacuum interlock of the booster. The PLC was equipped with an IEEE-802.3 Ethernet interface communicating directly with the PC/iRMX-III system. The system was run in stand-alone mode, and must be operated separately from the storage ring control system.

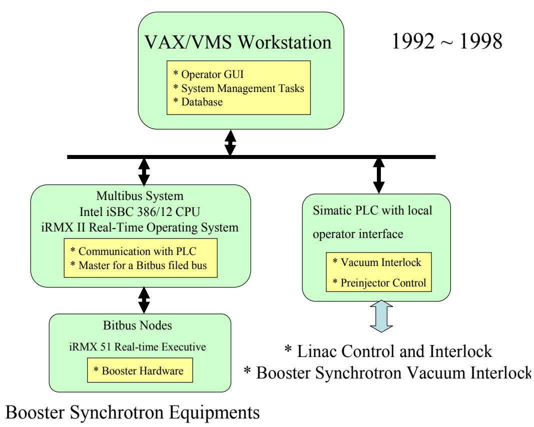

Figure 2. Functional block diagram of the original turnkey control system.

Integrated Control System

The major purpose of upgrading the control system is to: enhance the control efficiency and stability for light source operation; reduce the required maintenance resources, and prevent jeopardizing the system due to spare unit shortage. The first and partly upgrading of the control system of was carried out in 1998. As a result, it had improved system reliability and its response time. It also benefited to the upgrade project of the booster in raising electron beam energy from 1.3 to 1.5 GeV in 1999, since a number of major power supplies were replaced and was configured under the partly upgraded control system. Without the already prepared control system at that time, the booster 1.5 GeV upgrade would not be possible. Figure-3 shows the configuration of the partly upgraded control environment of the injector. The MULTIBUS system was replaced with VME crates. The BITBUS was eventually removed in 2000. The PLC system was retained due to the limited manpower available for the work.

PLC is the central core of the linac control system. It coordinates signals to and from the injector subsystem when it starts up and shuts down the linac. It communicates with the VME crate system via Ethernet network. The VME crate system runs a program to access the data of the PLC system. This VME crate functions as a protocol converter. The PLC is connected to the control network, and the VME crate communicates with the PLC over network connection.

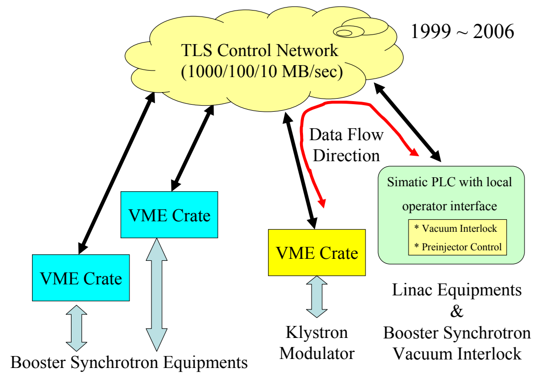

Figure 3. System block diagram of renewed control system in 1998. The signal flow between PLC and VME crate is highlighted.

New Control Environment

The partly upgraded system runs well since it was installed 1998. However, we have run into difficulty in maintenance of the PLC system. The existing system has all control and interlock functions in a large PLC. Separating functionality according to the hardware is not an easy task. The system is also complex because it combines all functionality in a single machine. The supports of this old PLC will soon become a problem. It is unavoidable that the old PLC has to be removed eventually and migrating to a full VME-based control system. The interlock logic is implemented using two simple PLCs. The new system utilizes one dedicated PLC to deal with the vacuum interlock logic while the other PLC handles the other interlock function of the linac system. Those functions without interlock requirement are connected directly to the VME.

A functional block diagram of the new control system is shown in figure-4. The new pre-injector control system consists of three parts. It includes the linac control interlock logic, the interlock for the booster vacuum system and the linac control subsystem. A proposed new hardware with a high-resolution VME analog interface provides better control flexibility. The alarm function of the digital panel meter generates a digital interlock signal to the PLC for analog alarm interlock. Accordingly, the PLC does not depend on the conversion of the analog signal to trigger analog alarm interlock The PLC runs only with digital input/output module. The two PLCs are connected to the VME crate through simple digital interface. All functions of the linac control system are controlled using the VME crate.

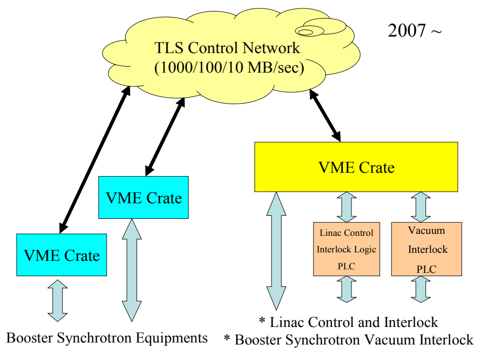

Figure 4. New control environment for LINAC system.

DISCUSSION

Three major changes of the LINAC control system have been made in the past 15 years for the following considerations: a) upgrade its functionality; b) replace out-of-date modules; c) integrate with the main control system. One of the major purposes of the upcoming upgrade tasks in 2007 is to improve its performance in terms of simplicity of device control. Its environment will be the same as the main control system of the NSRRC accelerator complex.

As a result, reducing the system delay of the communication between VME and PLC is one of the major improvements. In order to illustrate its effectiveness, the following top-up injection is taking as an example for demonstration purpose. During the process of top-up operation of the storage ring, both electron gun and the storage ring kickers have to be initiated simultaneously. It is because that the kickers disturb stored beam while adding electrons onto the beam. Consequently, it is important to minimize the disturbance as needed. However, observation shows that it is not the case in the "old" control system. The activating count of injection kickers is too high, 7 instead of 4, as shown in Fig. 5. It indicates that the delay between VME and PLC is more than 0.3 second. This delay causes the kickers lead extra cycles before gun does. The observed signals in figure-5 can be well understood as interpreted as follow. The top-up injection control program enables the injection kickers trigger and the gun trigger at the same time. However, due to the transmitting delay of the VME crate to PLC is about 0.3 second, it establishing unintentional three kicker cycles. After the beam current reaches the maximum level for top-up operation, the kicker trigger and gun trigger are immediately turned off. Again, due to the similar 0.3 second delay mentioned earlier, it produces three extra electron pulses without gaining to the stored beam. If the delay can be eliminated, both 3 leading kicker pulses and 3 following electron pulses will be eliminated as well. As a matter of fact, since these three extra pulses are found being loss nearby the injection septum of the storage ring producing undesirable radiation dosage. The cure of the signal delay can also improve the environment of health consideration. As shown in figure-6, the delay is reduced to 0.1 second in the new control environment. Only one extra cycle of the kicker pulse and gun pulse remains, respectively. The extra one cycle will be taking care of by modifying the timing system in June 2007.

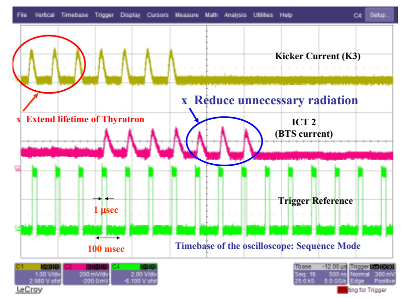

Figure 5. LINAC control system delay during injection control for top-up operation.

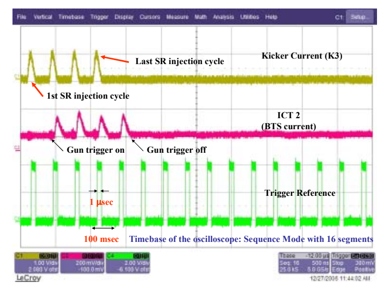

Figure 6. Reducing system delay of LINAC system during injection control in top-up operation.

SUMMARY

The migration of the LINAC control system started in July 2006 and is expected to be completed in June 2007. More than 60 % of the work has been done in 2006. This migrating process extends over one year due to the fact that only limited time slots are available while fulfilling top-up operation of the accelerator complex. All works are performed on every Monday morning of the weekly maintenance period. The new systems will simplify the overall control environment and equip with the required functionality. A drastic reduction in the system delay is a side benefit of this upgrade. This upgrade will also facilitate the control system in dealing with replacing out-of-date components and equipment associated with linac.

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