NEW CONTROL SYSTEM FOR THE 50 MeV LINEAR ACCELERATOR OF TLS

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Abstract

The pre-injector of the Taiwan Light Source (TLS) is consists of a 140 kV thermionic gun and a 50 MeV travelling wave type linear accelerator (linac) system. A linac control system has been renewed to avoid obsolescence. It is also utilized to improve performance, decouple the vacuum interlock logic from the linac control system, and provide a better control functionality for top-up operation. One VME crate system is dedicated for the linac control, the new hardware equipped with high resolution of analogue interface to provide better control. Vacuum interlock logic will be done via a dedicated programmable logic controller (PLC). The remained linac devices, which are necessary for sequential control such as door access interlock, klystron warm up, gun warm up, trigger interlock, gun high voltage interlock, klystron modulator high voltage interlock, water flow interlock, will be done by another PLC. Both interlock and sequential control of PLC will be controlled by the VME crate. All of the other functions without interlock or sequence requirement will be controlled by the VME crate directly as well. New control system is expected to provide better control functionality, better performance, easy for maintenance, and useful easy to add new hardware equipments.

INTRODUCTION

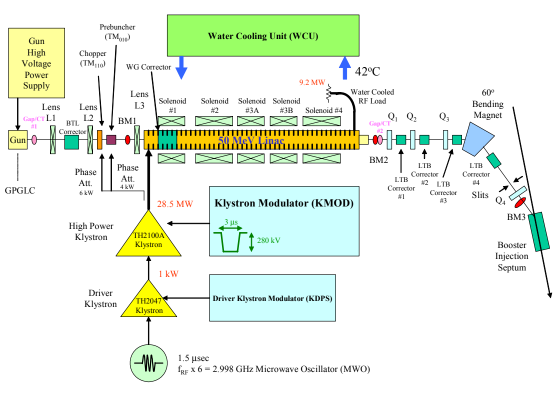

Figure 1: Synopsis of preinjector.

The pre-injector of the TLS comprises a 140 kV thermionic electron gun and a 50 MeV linac. The functional block diagram and layout of the pre-injector are depicted in Fig. 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 Fig. 1.

The origonal linac control system uses a dedicated PLC equipped with 10 MB/sec Ethernet interface since 1990. Besides, the vacuum interlock logic of the booster was tightly coupled with the pre-injector control system. This integral arrangement put difficulty on maintenance and replacement of some out-of-date devices in the pre-injector system.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 analogue 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 employed for the remaining linac devices which require sequential control in routine operation. Both interlock and sequence control PLCs are controlled by the respective PLCs located on the same VME crate. All other functions, are directly executed by the VME crate. The new linac control system is expected to provide better performance on control functionality and lighten maintenance burden.

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 and 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 inevitable. In dealing with this situation, a sideline in preparing the migration of the control environment has been exercised since July 2006.

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The new control system for 50 MeV linac is completed in May 2007.

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 Fig. 2.

The first layer was a VAX/VMS workstation which was employed to provide an operational interface 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 PLC was equipped with an IEEE-802.3 Ethernet interface communicating directly with the PC/iRMX-III system.

Upgraded Control System

The major purpose of upgrading the control system is: (1) enhance the control efficiency and stability for light source operation; (2) reduce the required maintenance resources, and (3) prevent jeopardizing the system due to spare unit shortage. The first and partly upgrading of the control system was carried out in 1998. It also benefited to the upgrade project of the booster in raising electron beam energy from 1.3 to 1.5 GeV in 1999. Fig. 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 VME crate communicates with the PLC over network connection.

New Control System (2007)

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 had all control and interlock functions in a large PLC. Separating functionality according to the hardware was not an easy task. The system was also complex because it combined all functionality in a single machine. The maintenance of this old PLC would soon become a problem. It is unavoidable that the old PLC had to be replaced 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 Fig. 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 analogue interface provides better control flexibility. The alarm function of the digital panel meter generates a digital interlock signal to the PLC for analogue alarm interlock. Accordingly, the PLC does not depend on the conversion of the analogue signal to trigger analogue 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 performed using the VME crate.

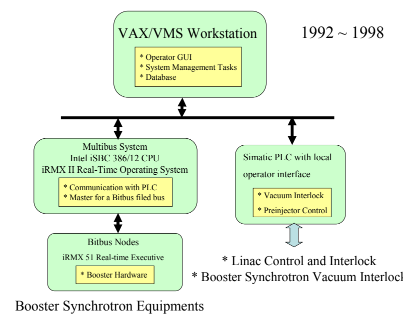

Figure 2: Functional block diagram of the original turnkey control system.

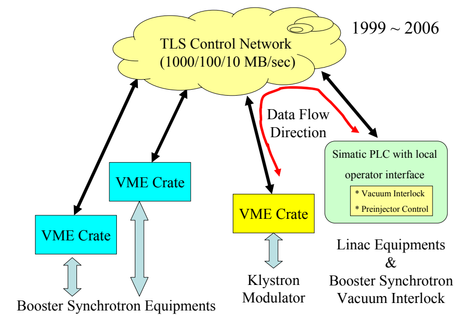

Figure 3: System block diagram of renewed control system in 1998. The signal flow between PLC and VME crate is highlighted.

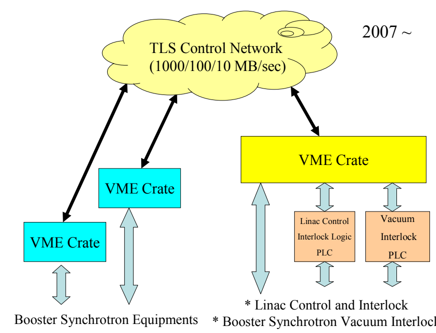

Figure 4: New control environment for linac system.

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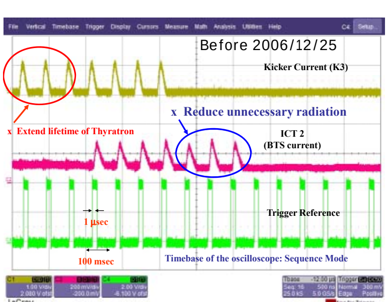
PERFORMANCE IMPROVEMENT

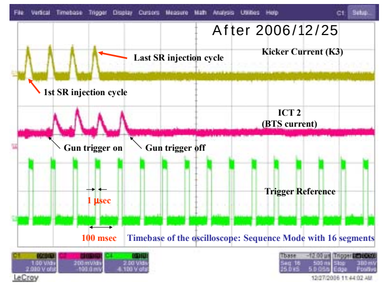
Four major improvements of the new linac control system are under the following considerations: a) upgrade its functionality; b) replace out-of-date modules; c) integrate with the main control system; d) modify timing system of top-up mode operation.

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. 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 the kickers disturb stored beam while adding electrons onto the beam. Consequently, it is important to minimize the disturbance as much as possible. However, observation shows that it is not the case in the "old" control system. 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 as show in Fig. 5(a). This delay causes the kickers lead extra cycles before gun does. The observed signals in Fig. 5(a) can be well understood as interpreted as followed. 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 transmitting delay can be eliminated, both of the extra leading kicker pulses and the following electron pulses will be eliminated. As a matter of fact, these three extra pulses are producing undesirable radiation dosage. The cure of the signal delay can also improve the environment of health consideration. As shown in Fig. 5(b), only one extra cycle of the kicker pulse and gun pulse remains, respectively.

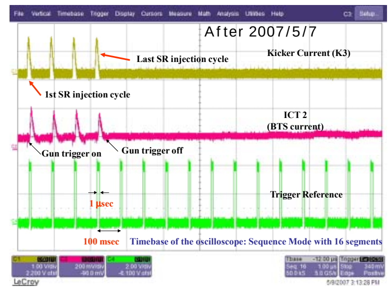
Only one extra cycle of injection timing system is eliminated after the timing control circuitry was modified in May 2007, as show in Fig. 5(c). The machine of NSRRC runs in top-up mode operation. Thus injection cycles of the Fig. 5 (a) (b) (c) are different. As shown in Fig. 5(c), the number of gun triggers is the same as the number of storage ring kicker fires. There is not producing extra radiation dosage in injection septum of the storage ring.



(a) Old control environment.



(b) New control environment.



(c) New control environment with modified timing control circuitry.

Figure 5: (a) Old control system with 0.3~0.4 second transmitting delay before December 2006. (b) The delay is reduced to less than 0.1 sec after December 2006. (c) The new control system has not produced extra trigger pulse after May 2007.

SUMMARY

The migration of the linac control system started in July 2006 and completed in May 2007. This migrating process goes through over one year due to little limited time slots available while fulfilling top-up operation of the accelerator complex. All works are performed only on every Monday morning of the weekly maintenance period. The new linac control system will simplify the overall control environment and equip with the required functionality. The system response time is drastically reduced. The timing control circuitry was modified also in this upgrade. The new control environment will also facilitate the control system in dealing with replacing out-of-date components and equipments associated with linac.

REFERENCES

[1] C. S. Chen, Jenny Chen, J. S. Chen, K.T. Hsu, K. K. Lin, C. J. Wang, "Control Integration for the Injector in SRRC", Proc. of the 1998 EPAC, Stockholm, p. 1658.

[2] C.S. Chen, C.J. Wang, Jenny Chen, J.S. Chen, S.H. Lee, K.H. Hu, K.T. Hsu, K. K. Lin, "Performance of the Rejuvenated Injector Control System in SRRC", Proc. of the 1999 PAC, New York, p. 682.

[3] C. Y. Wu, J. Y. Hwang, S.Y. Hsu, Demi Lee, C. J. Wang, Jenny Chen, K. H. Hu, C. H. Kuo, K. T. Hsu, K. K. Lin, "Rejuvenation of the linac control system for TLS", Proc. of the 2007 APAC, Indore.

