PERFORMANCE ANALYSIS AND IMPROVEMENT OF 50 MEV LINAC FOR THE TAIWAN LIGHT SOURCE

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Abstract

The performance of linear accelerator (linac) affects injector operation stability directly. In order to study and improve performance of the linac system for the Taiwan Light Source (TLS), some diagnostic devices and application programs are developed and setup for performance analysis of the 50 MeV linac. Integration of the current transformer signals which are acquired from linac entrance, exit and 60 degrees bending magnet exit within the control system was done. It enables beam charge value reading at the rate of 10 Hz in control system. Major beam characteristics related to transmission and energy spread were studied. The RF feed-forward control is continuously studied for improving energy spread for long bunch. This paper evaluates the performance of the linac system and presents the efforts to improve operation stability.

INTRODUCTION

The pre-injector of the TLS comprises a 140 kV thermionic electron gun and a 50 MeV linac. 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 into the booster. Synoptic layout of the linac system is given in Fig. 1.

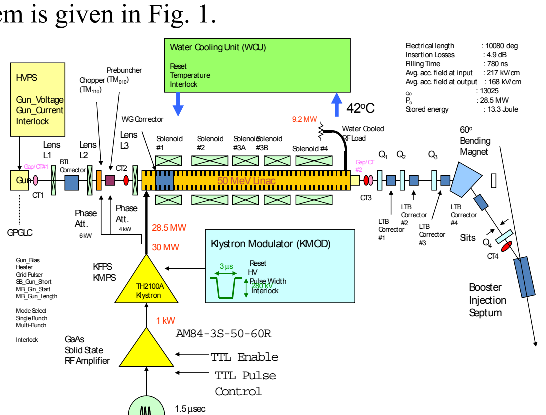

Figure 1: Synoptic of the 50 MeV linear accelerator system components of the TLS.

The origonal linac control system uses a dedicated PLC equipped with 10 MB/sec Ethernet interface since 1990. A linac control system had been renewed to avoid obsolescence about two years ago. It is also utilized to improve performance, decouple the vacuum interlock logic from the control system, and provide a better control functionality for top-up operation.

Beam quality of the 50 MeV linear accelerator is positively associated with flatness of RF field amplitude and phase. Both parameters will primarily depend upon the klystron modulator performance. Well tune of the pulse forming network (PFN), which cannot be achieved easily, is essential for good microwave pulse for the linear accelerator [1]. To eliminate tedious tuning process of the pulse forming network, RF feed-forward might be another alternative solution to accomplish the same mission. Not only can beam loading effects be compensated, but effects of slow drift due to various reasons can also be removed by RF feed-forward control [2]. A feasibility of the RF feedback control was studied recently at the linear accelerator of TLS. Purposes of this study are as side products of revision of low level RF system of the linear accelerator. Preliminary test which was done during the second quarter of 2007 showed a promising result. This paper will measure transmission and energy spread with integrator of current transformer signals.

LINAC CONTROL SYSTEM IMPROVEMENT

The linac control system was embedded in the originally delivered turnkey control system of the injector. The hierarchy of the system had three layers, as shown in Fig. 2(a) This system has been partly integrated with the NSRRC main control system in 1998 to enhance the operation efficiency. Fig. 2(b) shows the configuration of the partly upgraded control environment of the injector. A long-lead transformation process toward a new control system is unavoidable. In dealing with this situation, a sideline in preparing the migration of the control environment has been exercised since July 2006. The new control system for 50 MeV linac is completed in May 2007.

The new pre-injector control system consists of three parts is shown in Fig. 3. It includes the linac control interlock logic, the interlock for the booster vacuum system and the linac control subsystem. The alarm function of the digital panel meter generates a digital interlock signal to the PLC for analogue alarm interlock. Accordingly, the PLC that runs only with digital input/output module doesn't depend on the conversion of the analogue signal to trigger analogue alarm interlock. Two of them are connected to the VME crate through simple digital interface. All functions of the linac control system are controlled using the VME crate. The system

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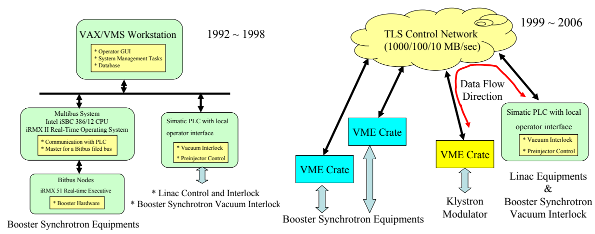
response time is much faster than the old system as shown in Fig. 4.



(a) (b)

Figure 2: (a) Functional block diagram of the original turnkey control system. (b) System block diagram of renewed control system in 1998. The signal flow between PLC and VME crate is highlighted.

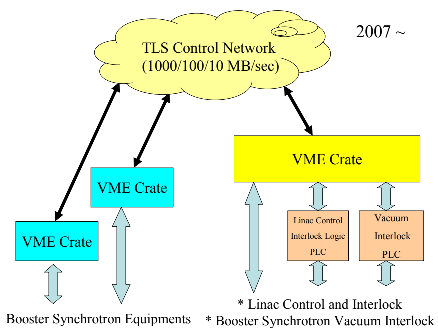
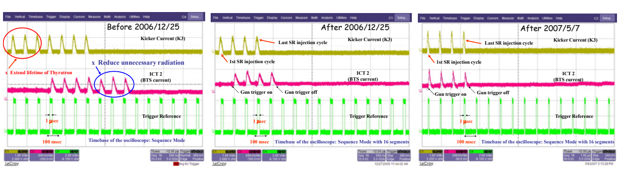


Figure 3: New control environment for linac system.



(a) (b) (c)

Figure 4: (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 second after December 2006. (c) The new control system with modified timing control circuitry has not produced extra trigger pulse after May 2007.

Benefit of New Control System

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. 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 shown in Fig. 4(a). After the beam current reaches the maximum level for top-up operation, the kicker trigger and gun trigger are immediately turned off. It produces three extra electron pulses without gaining to the stored beam. As shown in Fig. 4(b), only one extra cycle of the kicker pulse and gun pulse remains in new control environment. Only one extra cycle of injection timing system is eliminated after the timing control circuitry was modified in May 2007, as shown in Fig. 4(c).

UPDATE OF THE LINAC LLRF

The microwave system was composed of multiplier that derivates 2998 MHz from 499.654 MHz, a 1 kW GaAs solid state RF amplifier, and a high power klystron amplifier. The high power klystron is powered by an 80 MW PFN based modulator. An analogue vector modulator is placed in front of the GaAs amplifier to control the amplitude and phase of the RF field feed into the linear accelerator. An analogue vector demodulator is used to detect the RF signal from outlet of linear accelerator. The functional block diagram of the low level RF system for the linear accelerator of the TLS is shown in Fig. 5.

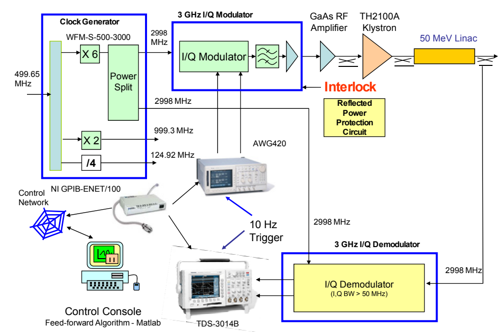


Figure 5: The block diagram of the low level RF system for the 50 MeV linear accelerator.

Preliminary Correction Test

Several correction tests of the RF feed-forward control have been performed. A simple algorithm was applied to compensate variation of the RF field by the approach of feed-forward control. The Fig. 6 demonstrates the droop at amplitude and phase of the RF pulse induced by 600 nsec electron bunch train can be improved by further correction.

Energy spread can also be reduced drastically when correction is applied as shown in Fig. 7; energy spread can be reduced from 4 MeV (FWHM) to less than 1 MeV (FWHM) slightly after correction at exit of linac. Electron bunch train length is 300 nsec in this measurement.

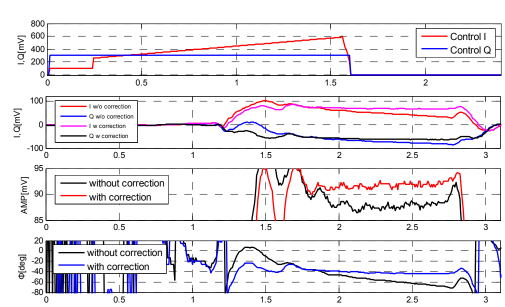


Figure 6: RF amplitude and phase waveform before and after correction with bunch train 600 nsec beam, both amplitude and phase are corrected simultaneously.

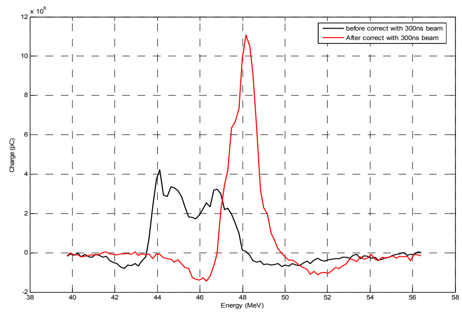
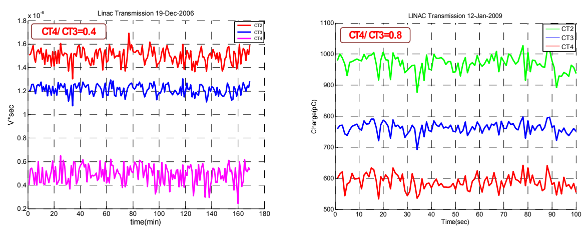


Figure 7: The RF amplitude and phase waveform before and after correction with bunch train length 300 nsec beam, energy spread is reduced simultaneously.

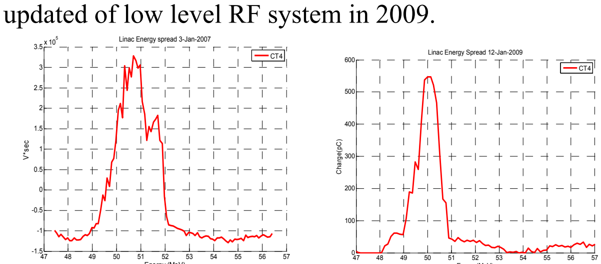
Transmission and Energy Spread Measurement

The gated integrators (Stanford Research Systems, Model SR250) integrate the current transformer (CT) signals which are installed on linac entrance, exit and 60 degrees bending magnet exit. The integrated value can be for control system 10 Hz reading and diagnostics. The only drawback of the integrator is complete baseline subtraction. The reason for baseline of current transformer isn't constant.



(a) (b)

Figure 8: (a) The transmission of pre-injector in December 2006. (b) The transmission of pre-injector after updated of low level RF system in 2009.



(a) (b)

Figure 9: (a) The energy spread measurement in January 2007. (b) The energy spread reduces to less than 1 MeV (FWHM) in January 2009.

The Fig. 8(a) shows transmission of the pre-injector in Dec 2006. The transmission of the pre-injector is increase after updated of low level RF system is applied as shown in Fig. 8(b) in Jan 2009. The new low level RF system reduces trigger jitter and increases RF output stability. The ration of CT4 to CT3 raises form 0.4 to 0.8.

The energy and energy spread are measured by spectrometer systems. The scan 60^o bending magnet current, energy defined slits and intensity sensor (CT4) are used in this study. MATLAB scripts are useful for access and analysis. The energy spread can be reduced drastically from 2 MeV to less than 1 MeV (FWHM) as shown in Fig. 9(a) and Fig. 9(b).

FUTURE PLANS

The correction tests of the RF feed-forward control have been performed at the 50 MeV linac of TLS. The flatness of amplitude and phase of the linear accelerator RF pulse can be improved after applying a simple RF feed-forward correction scheme. Continuing efforts on the improvement of correction algorithm, RF electronics and data acquisition are on going.

The GigE Vision cameras within the TLS control system can easily access the images through Ethernet network for various machine studies. The image quality is excellent and various exposure times are very helpful to increase dynamic range. The GigE Vision cameras will adapt to EPICS environment for diagnostics in the near future.

The CAEN V1721 digitizer (8 channel input, 500 MSamples/sec) captures the signals from CT1, CT2, CT3 and CT4 is shown Fig. 10. The integrated value of CT1~CT4 will be used to display on control console and archive to database of TLS. It takes out baseline slip of CT1~CT4 via MATLAB scripts. The low data is helpful to analysis and diagnostic. The efforts and experiences of this paper will be available shortly after the linac of TPS commissioning.

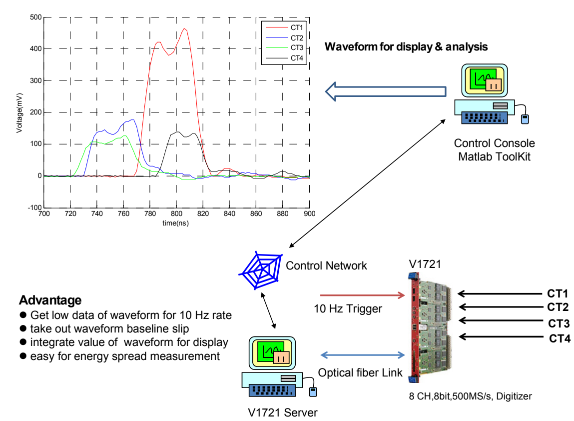


Figure 10: The block diagram of the CAEN V1721 digitizer for CT1, CT2, CT3 and CT4 waveform capture.

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