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# Design Study of Control System for Radiation Therapy System Based on 6 MeV X-band LINAC

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## 1. Introduction

Linear accelerator(LINAC) is used in various fields such as industrial, defense, medical, etc [1,2] because it is easy to control radiation energy or flow rate.

*KAERI* developed a robot-based radiation therapy system that can efficiently irradiate radiation in a short period of time. Unlike the old type which uses a single robot arm, two robot arms are used and the smart bed is linked to track the respiration. So that X-rays are automatically turned on and off. This robot was located on National Radiation Equipment Research and Fabrication Center.

This paper discusses the development of system of integrated X-band LINAC modules installed in smart robot therapy machines.

## 2. Design Feature

This section describes the configuration and results of the developed control system.

### *2.1 System Architecture*

The system is consist of remote control, therapeutic radiation source control system, hardware, interlock system such like Fig. 1. The remote control part is a part for receiving the data from LINAC and controlling the operation of the actual robot. It is composed of various devices and all hardware is connected to the control PC through local TCP/IP communication. In this system, RS-232(RS-485) to Ethernet device server (made by Solnae system) was used to change the communication method for RS-232 and RS-485 communication devices. In the Therapeutic Radiation Source Control System part, we developed an integrated control application called *XbandCS*, which allows us to monitor and control all the hardware in one main PC. In addition, the GUI is configured to respond to abnormal situations by adding alarms using log files and database to store parameters and status of equipment when they are changed. And interlock system is applied to each door at test sites for safety system stops high voltage supply and beam operation immediately if the door is opened.

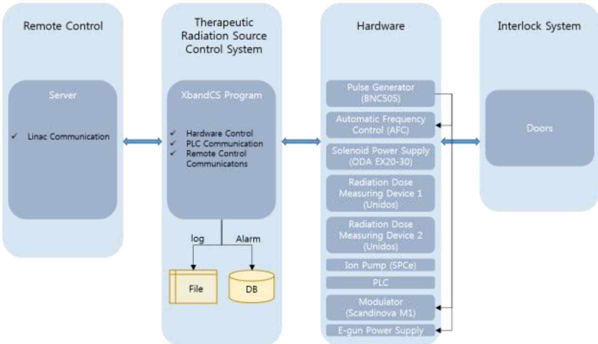

Fig. 1. Overall configuration of the control system

### *2.2 Application Design*

As shown in Fig. 2, 6 MeV LINAC was installed to the robot arm and the sockets of the equipment inside of radiation source module were placed in front of the module panel. Each device inside of the module was connected to the control box by cables of more than 10 m. Two Category. 7 cables over 15 m are laid between equipment on first floor and main control PC on second floor like Fig. 3 because prevent to be exposed to radiation. Two hubs are connected to each cable with considerations on data transmission traffic to prevent overload to the hubs.


Fig. 2. 6 MeV LINAC mounted on a robot installed on the first floor at *National Radiation Equipment Research and Fabrication Center*

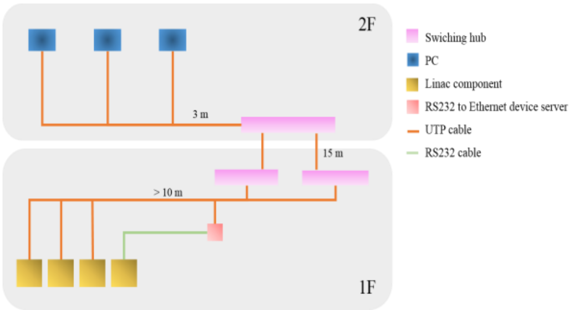

Fig. 3. Cable configuration between first and second floor laboratories.

Control application, *XbandCS*, was developed based on Microsoft foundation class(MFC) using Visual Studio. In the application, system control and monitoring are simultaneously performed. Monitoring parameters are ion pump vacuum level and radiation dose. Especially, during conditioning of the accelerating cavity, the vacuum is an important parameter [3], so vacuum values are displayed at the bottom of control GUI window so that they can be monitored at any time and the vacuum degree is displayed in a real time graph as shown in Fig. 4.

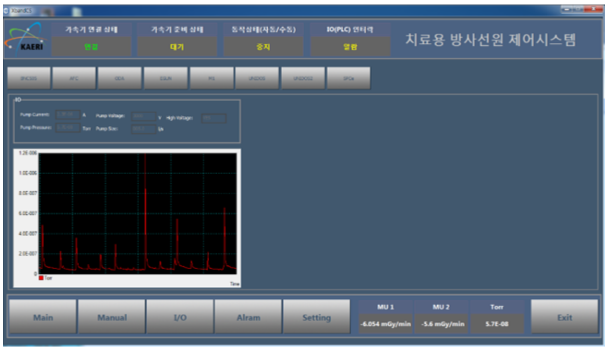

Fig. 4. Vacuum graph of control application *XbandCS*

Control program can be operated in two modes, these are, automatic mode and manual mode. Manual mode is commonly used in equipment conditioning phase like RF conditioning or electron gun aging. However, accuracy is required if LINAC is to be used with robot or for patient. When dose rate of X-ray reaches to the setting value, the robot must be stopped immediately. During the treatment time, ON/OFF should be repeated at certain timing. This is risky for doing manually. For that reason, automatic mode has been applied. The scenario for the automatic mode is shown in Fig. 5.

The remote control module receives and stores the beam index, desired dose value, and angle data of the robot arm. Also it checks connection status of each device and the current status of the interlock. If the interlock system is running, it turns on the alarm and laser beam (an alternative means of locating the beam because the actual X-rays are not visible). And then the user can change the status of LINAC to automatic mode.

*XbandCS* turns X-ray beam on and off with very high repetition rate to linked the signal($BEAMT/$BEAMF) from the remote control module. When dose rate reaches to desired value, the beam is immediately off. Equipment directly associated with turning X-ray on and off is the E-gun power supply and the signal generator (BNC505). Since the E-gun power supply can not instantaneously lower the voltage, it will turn off the X-ray by turning off the signal of ready-to-operate trigger signal generator.

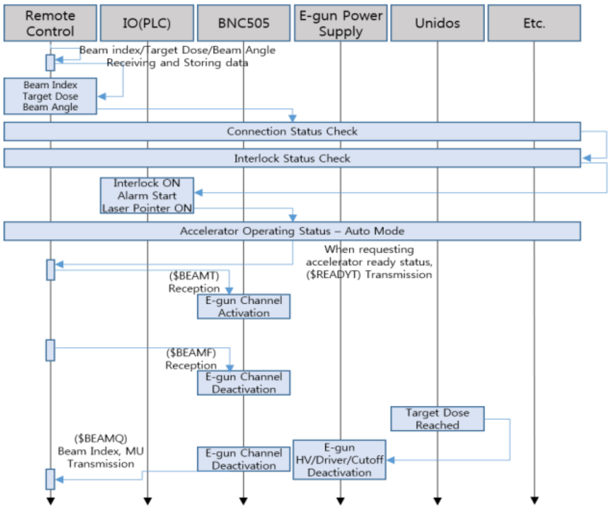

Fig. 5. Automatic mode scenario

Another important status of LINAC is the emergency situation. The emergency stop scenario is shown in Fig. 6. It is different from the planned suspension of the user, and it is suspension for the emergency situation. Emergency stop buttons were placed everywhere for usage in emergency situation. Button is used when there is subjective judgement so that X-ray can not be turn on irradiated. After pressing the button, not only the trigger signal to the E-gun power supply but also the high voltage, grid voltage and RF can be turned off to prevent accident. In addition to pressing the stop button, we supposed forty-eight lists that will stop LINAC operation, as shown in Table I.

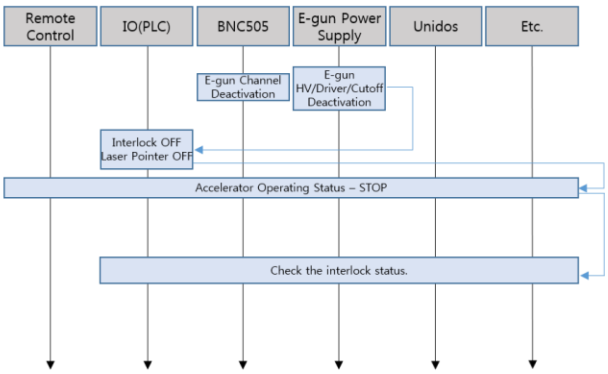

Fig. 6. Emergency stop scenario

Table I: Error message ID index

| ERROR Description | ID |
|---|---|
| Connection Failed | 1000~1008 |
| E-gun Interlock | 1020~1025 |
| Modulator Interlock | 1040~1067 |
| Slope – Invalid Value | 1080 |
| MU – Invalid Value | 1081 |
| PLC Interlock | 1090 |
| User Stop | 1100 |
| User Emergency Stop | 1101 |

Finally the program including functions mentioned above is produced shown in Fig. 7, and total control of LINAC is possible with this program.


Fig. 7. Control application *XbandCS*

### 3. Discussion

The equipment with RS-232(RS-485) to ethernet device server had a problem in data transmission and receiving as the length of unshielded twisted pair(UTP) cable was increased. We changed the baud rate from 9600 to 19200 bps so that response latency became shorter. Transmission and receiving delay of communication line should be maintained as short as possible, because ON/OFF signals in automatic mode need to be linked with patient's breath. We will investigate whether delay influences of the delay on the ON/OFF timing.

### 4. Conclusions

In this study, total control program for integrating and controlling the medical LINAC modules was developed and verified. Future research will continue to reduce delays between transmissions and receptions and minimize interference between the modules.

### REFERENCES

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