The Control System for a 2 MeV Tandem Accelerator used for Contraband Detection

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Abstract

The Contraband Detection System (CDS) is a system designed for detection of explosives and other contraband utilizing Gamma Resonance Absorption (GRA). In the CDS 9.17 MeV gammas are produced by 1.75 MeV protons interacting with a Carbon 13 target. The 2 MeV Tandem is capable of producing upto 10mA of C.W. proton beam. The Control System consists of two Allen-Bradley SLC500 series Programmable Logic Controllers (PLC). One resides at ground potential and the other is located inside the Tandem pressure vessel at 1 MegaVolt. Supervisory control and communication between the two PLCs is accomplished using the Allen-Bradley Data Highway Plus and fiber optics. Operation of the system is described.

1 Introduction

TRIUMF and Northrop Grumman have developed a new system for the detection of concealed explosives and drugs. The Contraband Detection System (CDS) consists of an H^- CUSP ion source at 40kV potential, a low energy beam transport (LEBT), the Tandem accelerator, a high-energy beam transport (HEBT), a target and detectors. The Tandem accelerator consists of two subsystems: one at ground potential, the second biased at the terminal potential. At ground potential is a variable high voltage power supply system, a SF_6 gas system, and two electron skimmers located at either end of the Tandem. At high potential is the terminal, which consists of a gas stripper system, two sets of triplet quad magnets for beam focussing, two sets of steering magnets, diagnostic collimators and the associated vacuum system. The Tandem Control System must also interface to the Operational Control and Support System, which handles the LEBT, and HEBT.

The High Voltage Power Supply (HVPS) [6] consists of a variable DC power supply, a resonant mode inverter and a transformer. The DC power supply is a standard 700 VDC 60 A regulated supply. The inverter converts a DC level to a sine wave using a LC resonant circuit with the primary of the transformer forming part of the inductance. A stack of 80 printed circuit boards on an insulated gap ferrite core forms the transformer. Each board contains 32 secondaries, each with a rectifier and doubler. The doubled secondaries are connected in series to obtain 12.5 kV per board. The 80 boards are then connected in series to achieve 1 MegaVolt. The high voltage output is adjustable by both the DC supply voltage as well as the operating frequency of the inverter. At present the prototype Proof of Principle (see Figure 1.) 2 MeV tandem is in operation on the Northrop Grumman site in Bethpage New York.

2 Requirements

As for any accelerator, the main requirement for the Tandem Control System is to provide the means to produce and maintain a stable high quality beam. The stability required for GRA is closely related to target thickness [2]. As shown in Table 1 the energy spread allowed is <12keV for the Chlorine reaction and < 25keV for the Nitrogen reaction.

The control system must also provide operator access for open loop control and diagnostics for all devices. The architects of the Operational Control and Support System specified National Instruments LabWindows/CVI control software. LabWindows/CVI takes LabView a step closer to

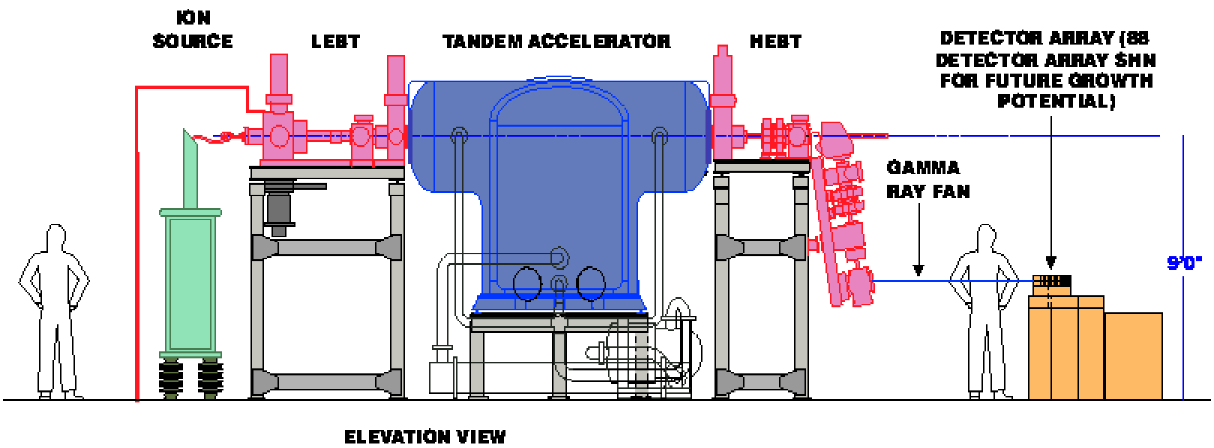

Figure 1: Elevation View

a full-blown control system by allowing the user to write application specific "C" code. Since space inside the terminal is extremely limited, duplicating this system was not practical.

	$^{14}N(\gamma,P)^{13}C$	$^{35}Cl(\gamma,P)^{34}S$
Proton Energy (MeV)	1.75	1.89
Energy Spread (keV)	<25	<12
Spot Size (cm)	0.6 x 2.4	0.6 x 2.4
Divergence (mrad)	12	12
Current (mA)	10	12

Table 1: CDS requirements for the selected reactions

3 Design and implementation

The control system uses "the standard model" two-layer architecture. The supervisory layer consists of a PC running LabWindows/CVI [4] with a third party driver HighwayView [5]. The device control layer is accomplished with two Allen-Bradley SLC5/04 Programmable Logic Controllers (PLC) [3]. One PLC resides inside the terminal biased at the High Voltage (HVPLC). The second PLC resides at ground potential (GNDPLC). The layers are networked with the Allen-Bradley Data Highway Plus (DH+). The PLC in the terminal is electrically isolated via Allen-Bradley fiber optic DH+ modems. Communication between the two PLCs is accomplished with the Global Status word. A 16-bit status word is transmitted over the highway each time the PLC receives the token. A watchdog system has been implemented to ensure communication is continuous. A read block and a write block have been set aside within each PLC for supervisory control and readback. The SLC 5/04, Allen-Bradley's top of the line for the SLC500 family, was selected since HighwayView only supports DH+.

3.1 Supervisory interface

Several techniques have been used to minimize traffic on the DH+. Status information has been mapped into a block of contiguous registers. N7:0 – N7:99 for the HVPLC and N7:100 – N7:130 for the GNDPLC. This allows the supervisory system to obtain all the status information from the PLCs in four highway packets. Similarly all setpoints and commands are sent to the N10:0 – N10:99 (HVPLC) , N10:100 – N10:130 (GNDPLC) registers. Setpoints and Commands are only sent when changed. The PLC rungs have been programmed to allow all interlocks to be bypassed by setting a BYP_{devicename}INT bit to 1. As well each limit switch may be "FORCED" to either of it's states by setting FRC_{devicename}OPEN to 1 or FRC_{devicename}CLOSED to 1. The supervisory software must provide the appropriate protection against unauthorized use.

3.2 HVPLC

The HV PLC is responsible for all the devices in the terminal. These include:

- four Quadrapole magnets
- two horizontal steering magnets
- two vertical steering magnets
- gas leak valve for the stripper
- +/- 1kV bias power supplies in the stripper
- 1kV electron suppressor power supply
- 2 cryo cold heads
- convectron vacuum gauge
- 2 cold cathode vacuum gauges
- Turbo pump
- 2- 4 segment collimators
- 2 ring collimators
- water circulator
- water temperature monitor

The PLC configuration consists of a SLC 10 slot rack with the SLC5/04 CPU, a scanner module, 4 - 4 channel thermocouple modules, a 32 bit 24VDC input module and a 16bit high current 24VDC output module. Connected to the scanner module is an Allen-Bradley Flex I/O terminal block I/O system which contains a Remote I/O adapter, 3 - 8 channel 12bit analogue to digital converters and 3 - 4 channel 12bit digital to analogue converters. The scanner and the Flex I/O system was selected to conform to space limitations. Custom manufactured hardware includes interface printed circuit boards for measuring the cryopump temperatures, terminal AC voltage and an independent fiber optic PLC power controller.

3.3 Gndplc

The Ground PLC monitors and controls all devices at ground potential and the hardwired connections to the Operational and Support Control System of the CDS. These include:

- SF_6 pressure, flow and temperature
- compressor for the cryopumps
- LEBT vacuum
- HEBT vacuum
- beam kicker enable
- 2- 5kV electron skimmer power supplies
- High Voltage power supply system
- Variac and AC contactor

The PLC also ensures power to the terminal is removed when the Tandem is evacuated. The ground PLC configuration consists of a SLC 10 slot rack with the SLC5/04 CPU, 3 - 4 channel 16bit analogue to digital converters, 2 - 4 channel 14 bit digital to analogue converters, a 32 bit 24VDC input module, 2 16 bit high current 24VDC output modules. Custom hardware consists of an interface/fast loop printed circuit board for the HVPS.

3.4 Control loops

There are three control loops utilized in the Tandem control system.

1. Stripper Gas PID

A PID loop in the PLC is used to stabilize the stripping gas pressure. The convectron vacuum gauge readback is monitored and the stripping gas leak valve is adjusted to maintain a fixed pressure.

2. High Voltage Fast Loop

A proportional loop has been implemented with analogue circuitry to provide fast regulation of the high voltage power supply. The circuit monitors the high voltage power supply via a resistor divider chain along the acceleration column. This value is compared to the setpoint of the HVPS with the error being limited to +/- 20kV. This error voltage is then fed to the inverter to adjust the operating frequency. The error is limited to keep the inverter frequency within the operating range for the transformer.

3. High Voltage PID

A PID loop is used to adjust the DC power supply based on the inverter's operating frequency. The PID monitors the error voltage fed to the inverter and adjusts the DC power supply's setpoint. This slow control eliminates running for long periods at frequencies significantly different from the transformer's optimum frequency.

4 Status

The Tandem was installed at the Northrop Grumman facility in Bethpage N.Y. in February this year. During initial commissioning 9.17 MeV gammas were produced with a target current of 50μA.

Acknowledgments

The authors would like to thank the CDS accelerator commissioning team particularly Steve Melnychuk and Roman Ruegg. The authors would also like to thank Mike LeRoss for his help with the interface boards. This work was conducted under USAF contract #F0865094C0097.

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