The 6th Symp. on Accelerator Science and Technology, 1987, Tokyo, Japan (© Ionics, Tokyo, 1987)

CONSTRUCTION AND PRESENT STATUS OF THE TRISTAN CONTROL SYSTEM

S. Takeda, A. Akiyama, K. Ishii, E. Kadokura, T. Katoh, T. Kawamoto,
E. Kikutani, H. Koiso, I. Komada, T. Kawamoto, K. Kudo, S. Kurokawa,
T. Naitoh, K. Oide, K. Uchino and J. Urakawa
National Laboratory for High Energy Physics
Oho-machi, Tsukuba-gun, Ibaraki-ken, 305 Japan

Introduction

In the autumn of 1986, TRISTAN was commissioned and gave the 1st event of positron-electron collisions at50 GeV in the total energy, on the day just 5 years from the ground breaking ceremony. The design and operation status of the TRISTAN accelerator has been presented elsewhere.[1,2] The TRISTAN complex consists of four accelerators, 200 MeV electron LINAC for positron production, 2.5 GeV electron and positron LINAC, 8 GeV Accumulation Ring(AR) which stacks the beams from LINAC to obtain sufficiently high intensity and 30 GeV Main Ring(MR) for the colliding beam experiments. The TRISTAN control system must provide the control functions and monitoring required to reliably direct the complex operation modes.

This report will present an overview of the control system for the accelerator including current status and clarifying what being peculiar problem to be solved before actual construction of a large accelerator control system.

In 1980 a detailed feasibility study of the cotrol system for the TRISTAN accelerator was started and this was followed by a basic design report.[3] The TRISTAN project was authorized by the government of Japan in April,1981 and actual detailed design and construction were started immediately. The first control system for the AR, which could be made an increase in the scale of the MR, was installed by the end of July, 1983. The MR system had been finished its installation by the end of March, 1986, including some indispensable changes for the system.

Basic Architecture

Fig. 1 shows the layout of TRISTAN after the manner of a bird's-eye-view. The machine equipment, like the other large accelerator, is too extensive for a single data-collection point to be practical. Therefore, in this case, data are collected at a number of places, edited and compressed as much as possible and then transmitted to the TRISTAN Central Control Room(TCCR). These collection subcenters are located at the ends and at the center of every arc of the MR, namely 12 subcenters are there. Five subcenters are arranged for the AR. These subcenters are attached to equipment buildings for magnet power supplies, Rf systems, vacuum systems, etc., from which many of the signals arise and to which control signals come. The central control building which is near one of the injection and extraction points of AR, is well located to permit a short path for direct transmission of fast monitoring signals from these lines.

There is no fundamental difference of kinds in the control requirements between a small and a large accelerator like TRISTAN, except the size of the machine and the amount of components. They are composed of the same types of components which individually have the same types of inputs and outputs. As a means of controlling the large scale machine, the distribution of several kinds of node components and suitable networks in connecting each node had been adopted in the TRISTAN accelerator,

The TRISTAN Control and monitoring system has 5 major signal paths. Fig. 2 illustrates schematically the distributed equipment nodes and the signal paths which connect the each node. The numbers of main nodes for the control system are listed in Table 1. These rather complicated networks are summarized as follows.

(1)N-to-Nnetwork forthe25 minicomputers.[4,5]
(2) Fiducial timing signals.[6,7,8,9]
(3) Safety and interlock controls.[10]
(4) Optical Fiber Video Network(OFVN).[11,12]
(5) CAble TeleVision(CATV) and LAN.[11,12]

(1): The machine control system uses 25 distributed minicomputers. The communication link between the minicomputers is a token ring network for the distributed industrial control system made by Hitachi. It connects stations by optical fiber cables with 10 Mbps transmission speed. The task organization for the minicomputers is functional rather than geographical, each computer controls all functions for related equipment through the 2.5 Mbps CAMAC serial highway. This CAMAC serial highway is extended over the crates from each control computer. The actual device interface to monitor and control the machine is the CAMAC module. The present system includes 179 CAMAC crates and 2,231 modules as shown in Table 1.

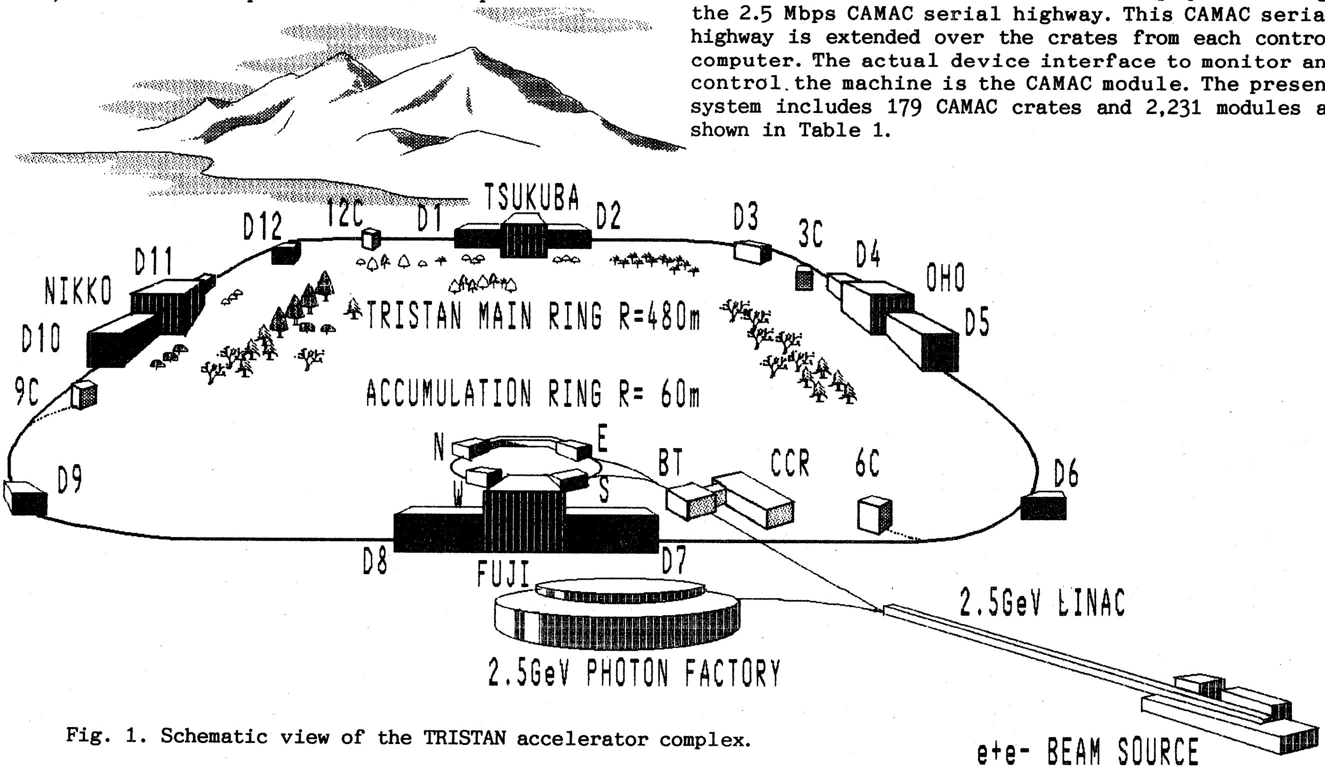

Fig. 1. Schematic view of the TRISTAN accelerator complex.

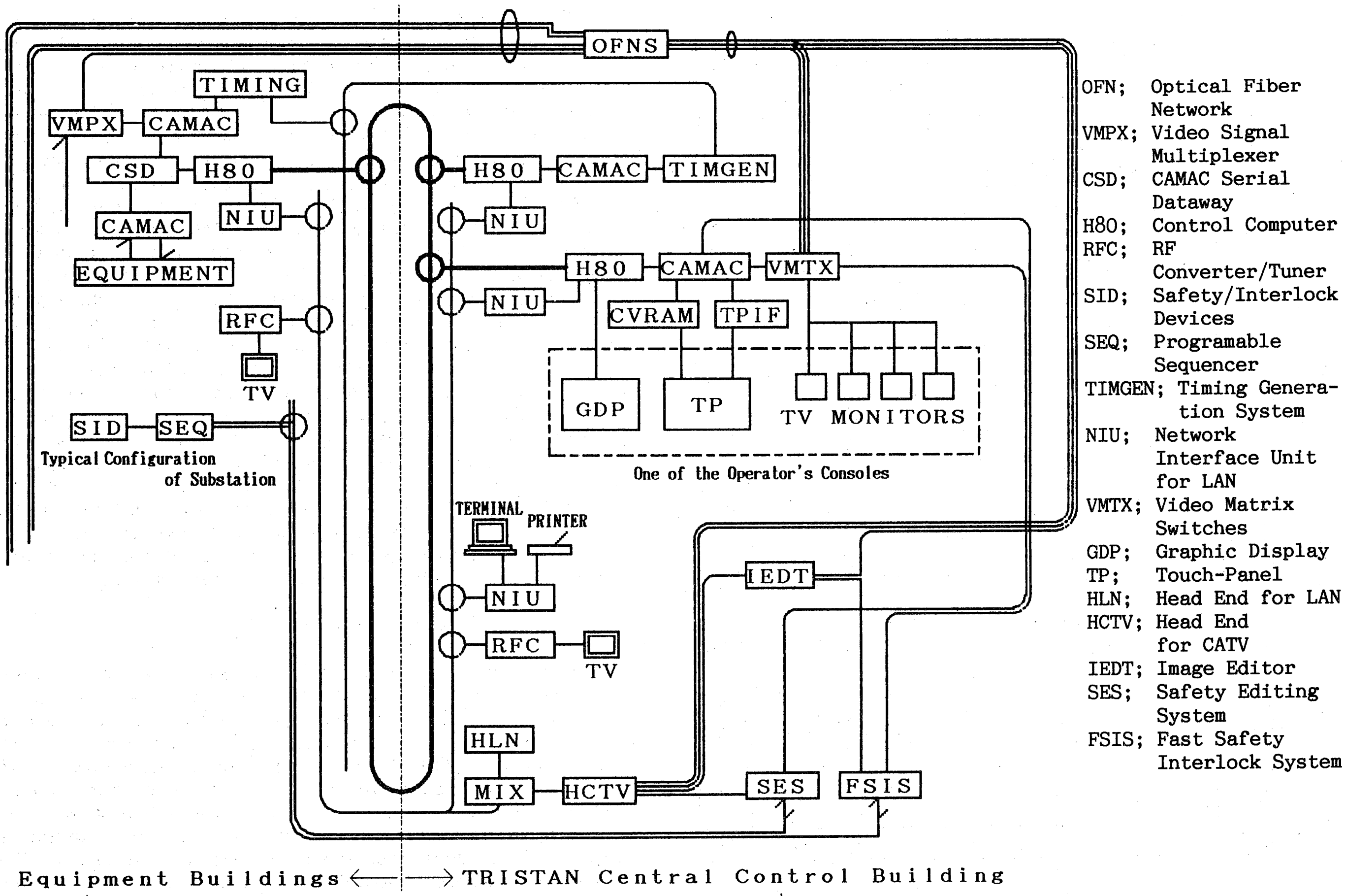

Fig. 2. Schematic description of TRISTAN control system.

(2): Timing signals for TRISTAN flow along two exclusive coaxial cables. One of them is used for slow (global) timing signals and the other is for fast (beam-synchronized) timing signals. The slow signals is required for starting an amplitude modulation of RF system, for gating the devices on a pulse-to-pulse basis at up to 100 Hz with the event signals, semi-automatic operations of the machines, etc.. The 100 Hz signal is created at the LINAC control room to give fiducial timing information in operation. The timing system distributes the slow signals using MIL-Standard 1553 with an 8 bit code of events. The fast timing signals are required for monitoring and handling the beam signals, for injection and extraction of the beam, for displays in the control room, etc.. The timing system divides the 508 MHz RF operating frequency to the circulation frequency of the beam and distributes a reference signal to the instruments. The fast timing system, which is formed by the phase locked loop using this signal, also allows precision (less than 200 psec) control of the trigger times of LINAC.

(3): Personel safety and interlock system consists of a distributed system. This system is geographically subdivided along local system lines and has a hierarchical structure of 13 Programmable Sequence Controllers(PSCs). Each PSC continuously loops through its stored program and handles about 80 input and 140 output signals. The duration of loop execution is about 25 msec. The system has two separate data-ways. One is used for pulse code modulated signals(PCM) which are transmitted by optical fiber cables and the other is so-called 9.6 kbaud polled modem. The optical fiber links connects the PSCs at subsystem level with a PSC at the supervisory level at the TCCR. The subsystem PSCs provide the interlock functions between their local devices and interact with the supervisory PSC through a limited number of summary signals. A transmissible rate of the PCM is 38 usec/cycle. The modem link allows a test of all input/output signals and graphic descriptions of related subsystem signals.

(4): Many video signals for the operation of TRISTAN are transmitted from subcenters to the TCCR through 154 optical fiber cables. These are images of the screen beam monitors, synchrotron light taken by TV cameras, screens of oscilloscopes, 100 TV cameras around the tunnels, etc.. There are also image data which are handled on the computers at some local stations. Those video signals collected at the subcenters are multiplexed at the local stations if necessary and then sent to the TCCR. Video signals collected at the TCCR are buffered and sent to a video signal matrix switch for operator's consoles and to the CATV system.

(5): The CATV system which is a sub-splited bi-directional system is used for broadcasting the operating status being edited at the TCCR and many images from the OFVN. The forward TV channels are allocated from 70 MHz to 300 MHz (33 TV channels) and the reverse ones from 10 MHz to 50 MHz. The total number of ports for CATV is 176. One of the forward channels, from 264.0 MHz to 270.0 MHz and the reverse channel from 33.9 MHz to 39.9 MHz are used for the LAN. Network interface units with RF converters are installed in each subcenter and the TCCR. A special use of the LAN is for the TRISTAN control computer system which has no means of communications to send information of the system console output from the computer itsself.

Man-machine interface to the control system is provided 6 independent control consoles.[11] One of them consists of two Touch-Panels(TPs), two graphic display monitors and ten TV monitors. One operator's console is supported by one minicomputer which is connected to the network. A TP system is composed of a character video RAM module, a 14" medium-resolution RGB video monitor, a touch-panel and a touch-panel controller module. The practically total number of displayed buttons on a panel is 42 buttons where each button composed of 3 lines of message and 9 characters in a line at maximum.

Table 1

Major Node Devices for TRISTAN Control System

BUILDING		MAIN NODE						
		COMPUTER	CAMAC CRATE	CAMAC MODULE	PSC	OPT. VIDEO	CATV	NIU
TCCR		14	16	157	3	154	25	10
LINAC			1	6		4	4	
BT		1	5	65				1
AR	E		11	149		4	4	1
	W	2	18	211	1	8	4	2
	S	1	5	54	1	4	4	1
	N	1	3	33	1	4	4	1
MR	D1		10	142		8	6	1
	D2	2	14	184	1	12	6	3
	D3		6	63	1	8	4	1
	D4		10	142		8	6	1
	D5	1	14	186	1	12	6	2
	D6		7	73	1	8	4	1
	D7		10	144		8	6	1
	D8	2	13	191	1	12	6	3
	D9		6	71	1	8	4	1
	D10		10	126		8	6	1
	D11	1	14	170	1	12	6	2
	D12		6	64	1	8	4	1
OTHERS						18	20	
TOTAL		25	179	2,231	14	154	129	34

Signal Transmission

One of the obvious problems caused by the size of a large accelerator, like TRISTAN, is that the lengths of many cables, especially those which need to go around the machine and the tunnel, have to be reduced their number, since the cabling costs for the large machine come to an enormous sum of money. The total cable lengths of the TRISTAN control system were about 450 km and the cost was about 170 Myen. If nothing was done to reduce the lengths, the estimated cabling cost would beabout 1,280 Myen due to theincreased cable lengths and the increased number of components. Generally speaking, as connecting points increase system troubles also increase and signal handling becomes difficult because of a noise-network formed by the complex wiring.

One of the means of reducing the cable lengts and the connectors is by multiplexing signals. Almost all control systems from small accelerators to large ones, a number of signals from or to devices are often multiplexed into a single cable for a special and single service. This signal handling must be extended into multiplexing many services into a single cable to reduce the number of cables and to allow various usage of transmitted signals. If all of the control signals were perfectly multiplexed in the TRISTAN system, the total cable lengths could be decreased to 200 km or less.

Reliability and Interface

As the number of components increases, the reliability of the individual components should increase to decrease the down time of the machine. The reliability of each electronic component is possible to be improved by selecting the components guaranteed by the good MTBF. For the last decade of the year, the reliability of the electronic components has increased by the integration on a single chip instead of the number of separate parts and by reduction in the number of connections using sockets. The interconnections using sockets and plugs becomes frequently the source of trouble.

The closest attention to the method of connection for the many devices to the control system must also be paid, since a number of source of trouble is on the connectors in this case. IN addition to this, many devices and many connectors have an incresing influence on the cost of the control system for the large machine. CAMAC was used for the interface system in the TRISTAN machine control, since it was the most popular standard at that time and there was no time enough to develop a new interface system. CAMAC crates and modules are relatively expensive and usually required junction and distribution boxes to connect with the accelerator components to control the individual signal requirements. We can suggest for an interface system of a future large accelerator that development costs and time for a new interface system should be taken into account to reduce the interface costs and to increase the reliability of the system in the long run. As the computer, which stands long use and hard duty, is easy to obtain nowadays, development of an interface system with processing ability in the equipment of the accelerator is a pressing need. The interface component will have to be using a single-chip microcomputer with on-chip I/O devices together with firmware for an interpreter and for a useful network communication.

Distributed System

Another problem come from the size of a large accelerator is how to distribute the computer system of the control. If the systen had the distributed processors only as a slaves for a central computer, it would face a difficult limitation on the number of simultaneous real time tasks in operating the accelerator complex. The control facilities should be supplied by a high-speed network connecting computers which include dedicated ones to specialized tasks. The high-speed network should fully and preferably be extended to the distributed devices to give direct communication without using so-called gateways. This is very importtant to avoid a traffic jam in the communication dataway.

References

[1] T.Nishikawa: "Status Report of TRISTAN Construction", Proc. 1985 Int. Symp. on Lepton and Photon Interactions at High Energies, Kyoto, (1985) 791.

[2] G. Horikoshi and Y. Kimura: "Status of TRISTAN", Invited talk at 1987 Particle Accel. Conf.

[3] H.Ikeda, et al.: "Design of the Control System of TRISTAN", IEEE Trans. Nucl. Sci. NS-28 (1981)2359.

[4] H.Koiso et al.: "Performance of the TRISTAN Computer Control Network",IEEE Trans. Nucl. Sci. NS-32(1985)2068.

[5] S. Kurokawa et al.: "The TRISTAN Control System", Nucl. Instr. and Meth. in Phys. Res. A247(1986)29.

[6] K. Ishii and E.Kadokura: "Timing System for TRISTAN AR", KEK Report 84-15.

[7] K. Ishii et al.: "Beam Synchronization for TRISTAN AR", 5th Symp. Accel. Sci. Tech., (1984)329.

[8] J. Urakawa et al.: "Bucket Matching System between TRISTAN AR and MR", Contributed to the 1987 Particle Accel. Conf.

[9] M.Kikuchi et al.: "Bucket Selector and Transfer Timing in TRISTAN", Contributed to this symp.

[10] S. Takeda et al.: "Safety and Interlock System for TRISTAN", Contributed to the 1987 Particle Accel. Conf.

[11] S. Takeda et al.: "Man-Machine Interface of TRISTAN", IEEE Trans. Nucl. Sci. NS-32(1985)2062.

[12]T.Katoh et al.:"Communication System forthe TRISTAN Accelerators", Contributed to the 1987 Particle Accel. Conf.