SAFETY AND INTERLOCK SYSTEM FOR TRISTAN

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Introduction

This report describes alarm and interlock system of TRISTAN, concentrating on personnel safety. The basis of TRISTAN machine-control system (TMC) is an N-to-N computer network and KEK NODAL which offers high software productivity [1],[2],[3]. TMC achieves high flexibility of operation both for normal operation and for the fast commissioning. However, to assure the safety of personnel and the TRISTAN machine operation, the safety system has to continue functioning during TMC failure as well.

A distributed safety and interlock system (DSIS) is used for diversification of risks in TRISTAN system. DSIS is functionally subdivided along local system lines and has a hierarchical structure of 12 programmable sequence controllers (PSCs). Optical fiber links connect the PSCs at subsystem level and a PSC at the supervisory level of TRISTAN central control room (TCCR). The subsystem PSCs provide the interlock functions between their local devices.

The local PSCs interact with the central system through a limited number of summarized signals. The central PSC provides the interlock functions between the subsystems and interacts with an operator's panel.

Personnel safety is based on a system of electrical interlock keys, emergency push-buttons around the tunnel, at the entrance gates or in the control room.

Operator Interface

As DSIS must continue functioning in case of a TMC failure, it interfaces with the machine operator through a classical synoptic operator's panel, incorporating LED lamps for DSIS state indication, two push-buttons for emergency stop, two for alarm acknowledgement and 13 push-buttons and 3 key-switches for setting machine status. The pannel lay-out is shown in Fig. 1. It is mounted on the right side operator's console (OPC) installed as shown in Fig 2. The operator's panel carries an audible alarm and its color displays are interpretable from the operator area.

General purpose interlock displays are shown on the top of Fig. 2. These displays are made of 27" TV monitors and drived by character video-RAMs (CVRAMs) [4]. The CVRAM is a CAMAC module generating a composite video signal or separate TTL video signals both in 8 colors.

DSIS Operational States

Fig. 3 shows the DSIS operational states in a state transition diagram. The diagram shows the operational state transitions at the DSIS supervisory level of TCCR. The states and transitions are described briefly below.

DSIS Stand-by: All subsystems are in a safe condition to operate TRISTAN. The transition to the "Beam On" state is only possible from this state.

DSIS Beam-On: This state is entered from the "Stand-by" state if conditions follow those required for starting of an injection of the beam. TRISTAN can be operated continuously in this state. The state signal is required by the local units influencing their behaviour to alarm conditions.

DSIS Emergency Shutdown: A seriously abnormal condition has been detected so that all the TRISTAN machine has to revert to a safe condition as fast as possible. This state involves shutdown of magnet and RF power supplies. Return to the "Stand-by" state can only be accomplished by a reset button after removal of the cause and operator acknowledgement.

DSIS Full Shutdown: This state corresponds to the transition from the "Emergency Shutdown", "Inhibit-Beam" or "Stand-by" state. Depending on the machine status, this state is generally initiated by operators. Transition from this state to the "Stand-by" state is also initiated by operators through the "Inhibit-Beam" state.

DSIS Inhibit-Beam: This state is entered from the "Beam -On"or "Stand-by" state if conditions do not follow those required for the states. This state is also used to allow manual intervention of the beam. The state puts the beam-stopper in and opens primary circuit-breakers of the power supplies for beam transport magnets.

Start of Operation: Transition from the "Stand-by" to the "Beam On" state caused by turning the key-switch on and actuating the BEAM-ON push-button switch.

End of Operation: Transition from the "Beam On" to the "Stand-by" state caused by turning the key-switch off.

Inhibit: Transition from the "Stand-by" or "Beam-On" state to the "Inhibit-Beam" state. This state is initiated if one of the subsystems sends an inhibit signal which depends on the DSIS interlock requirements and status of the other subsystems. If an abnormality of the former two states is not serious enough to complete shutdown, the beam stopper can be actuated and further

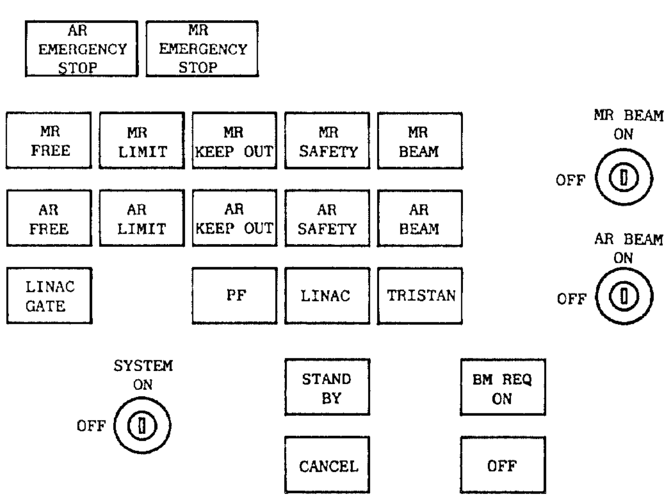

Fig. 1. A synoptic operator's panel.

Fig. 2. TRISTAN control room and Operator's console.

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beams are inhibited. Return to the "Stand-by" state can only be accomplished by a reset push-button switch after removal of the cause and operator acknowledgement. This transition is also set to allow manual intervention of the beam by the signal through TMC.
Emergency Shutdown: Transition from the "Stand-by", "Beam-On" or "Inhibit-Beam" state to the "Emergency Shutdown" state. This transition can be dictated by the DSIS interlock requirements and states of the other subsystems.
Full Shutdown: Transition from the "Stand-by", "Emergency Shutdown" or "Inhibit Beam" state to the "Full Shutdown" state. An operator initiates this transition turning the key-switch off.

DSIS Implementation

Although the PSC has been selected for DSIS, the actual implementation of the system depends on a number of factors, such as transmittability of signals, input and output configurations, reliability and fail safe consideration.
PSC: Since the interlock requirements will probably be subject to change as soon as possible by operational experience with TRISTAN, flexibility is an important requirement for DSIS. Behavior for modification of DSIS should never introduce special time delay. DSIS should be ever active in any case, then it has been investigated from the point of view of reliability.

The PSC has been proposed because they permit a high system flexibility, self testing facilities and have proved their reliability in many industrial installations. All PSCs for DSIS are based on the Yasukawa Memocon-SC.

Each of the PSCs continuously loops through its stored program and it is responsible for its own safety and interlock functions. The duration of loop execution depends on the number of instructions, but is about 25msec or so. Each PSC of subsystems handles about 80 input and 140 output signals.
Cabling and Input/Output Arrangement: The distance of the subsystem PSC from local units is shorter than 300 m, while the maximum distance from the subsystem PSCs to the supervisory one is 2,000 m. The cables, being jacketed by non-halogen flame-retardant material and of a twisted pair with thin copper film shield, are used from each PSC to local units.

Both inputs and outputs should be intrinsically fail-safe. This means for the inputs that the drive current source should be at the PSC and that the absence of input signal corresponds to the unsafesituation. In this way, both a short circuit and an open circuit of the wire result in a DSIS action into the safe direction. The same reasoning results in the power source location for the DSIS outputs. An output of the PSC is connected to a relay coil at the local unit. The contact in the local unit is normally-open type which closes to transmit a safe condition, that is, the coil is energized during safe condition.

The subsystem PSCs interact with supervisory central PSC through a limited number of summary signals of each PSC, those are 16 inputs and 16 outputs for every subsystem PSC. The summarized signals are transmitted using optical fiber links. The same fail-safe idea as metal cables on the subsystem levels is introduced into the optical transmission lines.

Since an optical fiber transmission system has such excellent properties as low loss, non-inductivity and

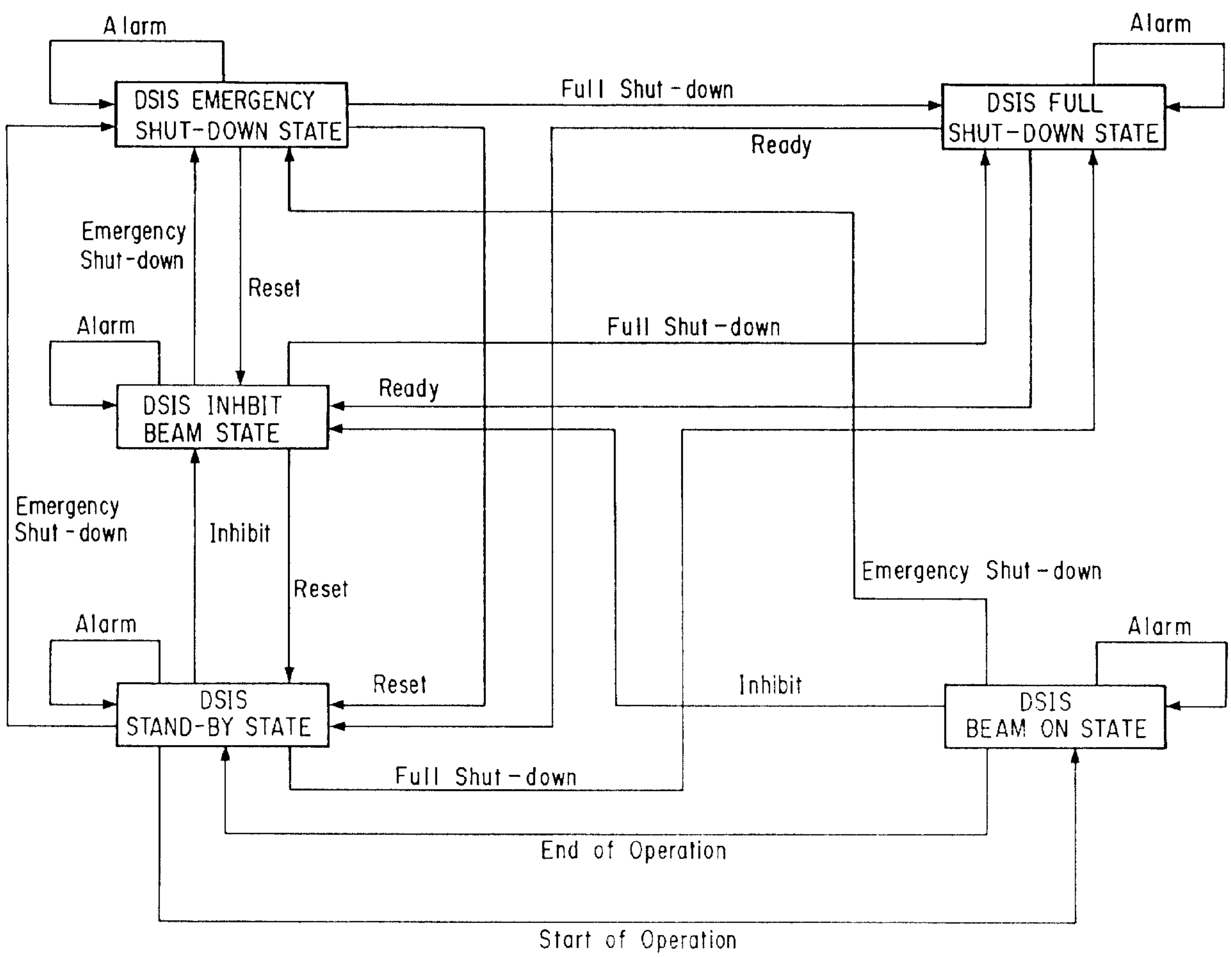

Fig. 3. A state transition diagram of the DSIS.

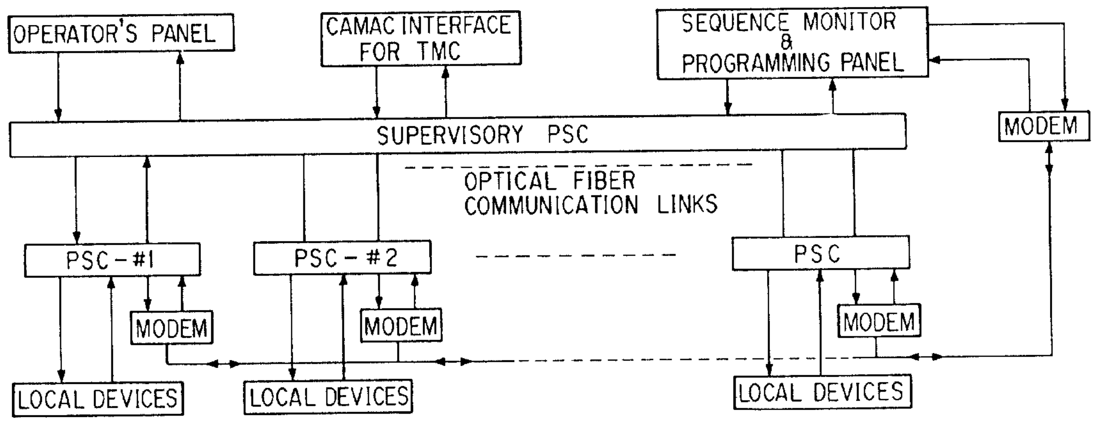

Fig. 4. A schematic description for the DSIS.

high insulation, it is capable for long distance transmission of the DSIS. A pulse code modulation (PCM) system is applied to the fiber transmission devices. DSIS has adopted two-way transmission using time division multiplexing techniques.Its transmissible rate is 38 usec/cycle.

Fig. 4 shows schematic description for DSIS. This description of the system includes a separate means of communication, modem link along TRISTAN, which is useful for an operator at the TCCR to test all input/output signals of each subsystem PSC. In addition, the signals transmitted by the modem are used for graphic descriptions of subsystem signals. Although the DSIS and TMC are almost independent with each other, CAMAC modules link the central PSC to the TMC in order to make an exchange of important information about safety.

Personnel Safety: Personnel safety is based on distributed electrically interlocked keys, gates and emergency push-buttons around TRISTAN. An electric key-storage is shown in Fig. 5. The key is usually locked by the DSIS, however, it is addressable with a correct ID code read by an ID-card-reader and possible to take out the key when the DSIS stands at the "Full Shut-down" state. Fourteen sets of those devices are installed around TRISTAN. The only person having the key is accessible to the controlled region through gates regulated by the DSIS.

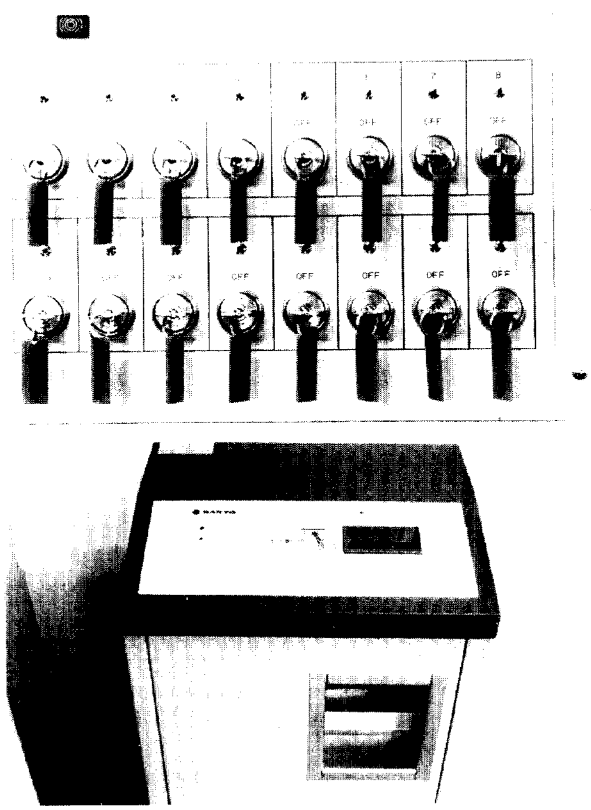

Fig. 5. Photograph of an electric key-storage.

A concentrated alarm panel which is called "Yellow-Box" after its color, is equipped in the controlled region every 30 seconds on foot. Fig. 6 shows the "Yellow-Box" incorporating an emergency push buttons, an audible alarm, warning lamps and a telephone jack. TV camera to monitor the tunnel is also equipped near the "Yellow-box"[5].

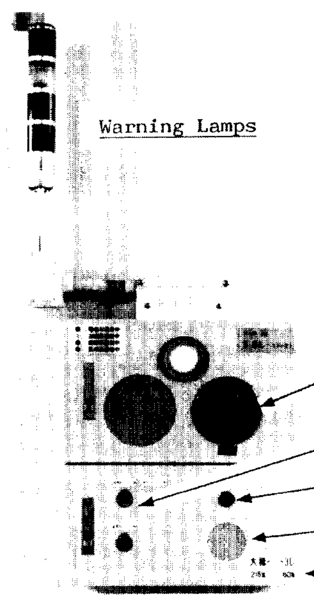

Fig. 6. Photograph of a concentrated alarm panel.

Acknowledgements

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