

# HARDWIRED INTERLOCK SYSTEM WITH FAULT LATCHABILITY AND ANNUNCIATION PANEL FOR ELECTRON ACCELERATORS

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## Abstract

A hard-wired interlock system is designed, developed, installed and tested to ensure healthy status for interlock signals, coming from the various sub-systems of electron accelerators as digital inputs. Each electron accelerator has approximately ninety-six interlock signals. Hard-wired Interlock system consists of twelve-channel 19" rack mountable hard-wired interlock module of 4U height. Digital inputs are fed to the hard-wired interlock module in the form of 24V dc for logic 'TRUE' and 0V for logic 'FALSE'. These signals are flow signals to ensure cooling of the various sub-systems, signals from the klystron modulator system in RF Linac to ensure its healthy state to start, signals from high voltage system of DC accelerator, vacuum signals from vacuum system to ensure proper vacuum in the electron accelerator, door interlock signals, air flow signals, and area search and secure signals. This hard-wired interlock system ensures the safe start-up, fault annunciation and alarm, fault latchability, and fail-safe operation of the electron accelerators. Safe start-up feature ensures that beam generation system can be made ON only when cooling of all the electron accelerator sub-systems are confirmed, all the fault signals of high voltage generation system are attended, proper vacuum is achieved inside the beam transport system, all the doors are closed and various areas have been searched and secured manually. Fault annunciation and alarm feature ensures that during the start up and operation of the electron accelerators, if any fault is there, that fault signal window keeps on flashing with red colour and alarm is sounded till the operator acknowledges the fault. Once acknowledged, flashing and alarm stops but display of the window in red colour remains till the operator clears the fault. Fault latchability feature ensures that if any fault has happened, accelerator cannot be started again till the operator resets that interlock signal. Fail-safe feature ensures that, if any digital input changes its status from healthy (logic 'TRUE') to unhealthy (logic 'FALSE'), this hard-wired interlock system trips beam generation power supply and high voltage generation system of electron accelerator. On the front panel of the system, LEDs are provided to show the signal status and its Interlock enable status. This paper describes about the hard-wired interlock system with fault latchability and annunciation panel for electron accelerators.

## THE HARDWIRED INTERLOCK SYSTEM WITH ANNUNCIATION

Figure 1 shows the pictorial view of two numbers of twelve channel module of Hardwired Interlock System with fault latchability and annunciation panel installed in the control room of 10 MeV EBC Linac. The figure shows the status of various interlock signals of the Linac when the beam is OFF. It is showing that all the five sputter ion pumps (SIPs) are ON to maintain the vacuum, the left and right door of room no 121 is closed and mobile shield is closed. The unhealthy interlock signals are displayed through the red colour window of annunciation panel whereas the healthy interlock signals are displayed by green colour window. The operator has acknowledged the healthy status of healthy interlock signals and hence both the signal LED and interlock enable LED of the right panel are ON for the healthy interlock signals.

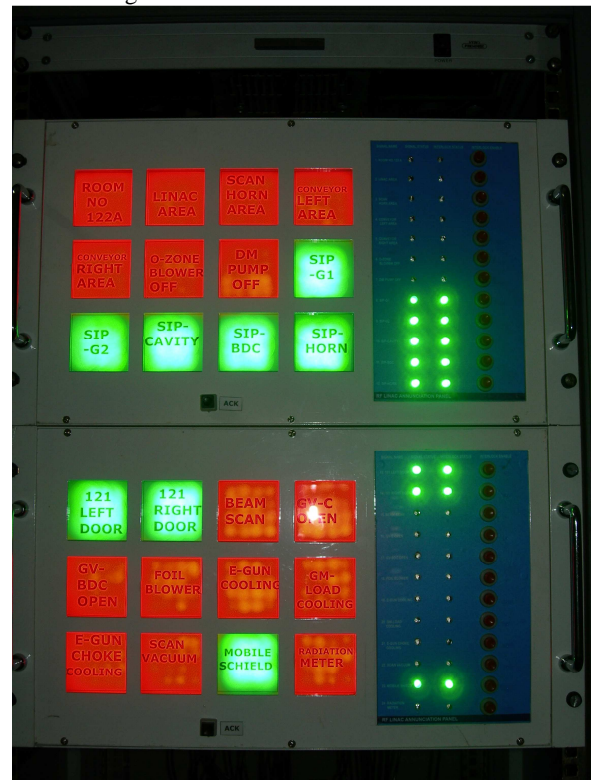


Figure 1: Hardwired Interlock System with Fault latchability and Annunciation Panel

## INTERLOCK SIGNAL

The interlock signals of electron accelerator are fed into the form of 24V DC for logic “Healthy” and 0V DC for logic “Unhealthy”. The annunciation panel shows the green colour window for the healthy signals and red colour window for unhealthy signals. The left window panel is the annunciation panel and the right blue panel is the part of hardwired interlock system. The column of the LEDs of hardwired interlock system shows the interlock signal status. The signals are fed through a mil-grade two pin circular connector at back panel of the module.

## SAFE STARTUP

The safe start up of electron accelerator is achieved by the hardwired interlock system. The second column of LEDs of hardwired interlock module shows the interlock enable status of interlock signals. The third column of hardwired interlock module is interlock enable push buttons, which is pressed by operator to enable the corresponding interlock signal of the same row. For example if the left door is closed, unless operator acknowledges its closed status by pressing the interlock enable push button, the second LED of the same row does not glow. Each 12 channel hardwired interlock module generates three potential free closed contacts, if all the twelve interlock signals are healthy and operator has acknowledged its healthy status by pressing the twelve interlock enable push buttons. Thus unless all the interlock signals are healthy, and acknowledged by the operator, this hardwired interlock system does not permit the operator to make the accelerator ON.

## FAULT ANNUNCIATION AND ALARM

Any unhealthy interlock signal is a fault condition for the operation of the accelerator. If any interlock signal is in unhealthy status, its fault status keeps on flashing in red window and an alarm buzzer is ON, unless acknowledged by the operator by pressing a black colour square push button mounted in each module and common for all the twelve fault signals of the module. Once operator presses this acknowledge button, flashing and alarm sound stops, but red colour of the signal window of annunciation panel remains ON, till the faulty signal becomes the healthy signal. The LED for the particular interlock signal in the first column of right side hardwired interlock system remains OFF unless that fault is attended and signal becomes healthy. The signals for the annunciation panel is generated in the form of potential free closed or open contacts, generated from the 24V dc or 0V dc signal fed in the back panel for each interlock signal. A micro-controller based system is inside the each twelve channel module to provide annunciation, flashing and alarm feature.

## FAIL SAFE OPERATION

If any fault occurs during the operation of the accelerator, the three closed potential free output contacts of the particular module in which fault occurs, become open. Once the closed contact becomes open, the

accelerator is automatically tripped. This ensures the fail safe operation of the accelerator. That is whenever a fault occurs for any interlock signals; it leads to the tripping of the accelerator. In any electron accelerator, once the beam generation system and high voltage generation system is tripped, the radiation source is OFF and hence leading to a safe condition. For example due to any reason if the vacuum falls below the  $10^{-5}$  torr level in the linac, the gun modulator system, the klystron modulator system and filament power supply of the electron gun is tripped, hence putting off the electron beam and radiation source.

## THE FAULT LATCHABILITY

Fault latchability feature ensures that if any fault has happened during the operation of the accelerator, the accelerator cannot be started again till the operator first attends that problem and signal becomes healthy and then operator enables that interlock signal by pressing interlock enable button. For example due to any reason if the vacuum momentarily falls below the  $10^{-5}$  torr threshold limit, the vacuum interlock signal becomes faulty and accelerator is tripped. After that suppose that vacuum signal becomes healthy, without this fault latchability operator has no idea that due to which reason the accelerator is tripped. In this system even if the vacuum improves and the first column LED corresponding to vacuum signal becomes ON, the second column LED of vacuum signal row remains OFF and fault is latched. By observing the particular module operator comes to know that accelerator is tripped because of vacuum failure and the vacuum has improved back. Now the accelerator can be made ON only when the operator enables that vacuum interlock signal by pressing the interlock enable push button of that row.

## CONCLUSION

The hardwired interlock system with annunciation, alarm and fault latchability is a standalone system. It ensures the safe start up of the accelerator. It ensures the fail safe operation of the accelerator. It provides fault latchability to enable the operator, to analyze that due to which reason accelerator was tripped. The total system comprises of five or six numbers of twelve channels, 19 inch rack mountable, and 4U height hardwired interlock modules with annunciation panel. This makes the hardwired interlock system modular in nature where as per the evolution of requirements during the installation of the accelerator, further modules can be added. The hardwired interlock system does not have any micro-controller or embedded PC and thus it does not have any software reliability testing requirements, which makes it more reliable.

## REFERENCES

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