A VME Based Quench Protection Monitor for the Tevatron Low Beta Quadrupoles

S. Lackey, C. Briegel, L. Chapman, R. Flora, K. Martin, and T. Savord *, F.N.A.L.**

Abstract

A VME based quench protection monitor system has been designed and installed at both low beta locations in the Tevatron. Fixed-target and collider mode operations have been successful. One VME based system protects all of the high current circuits in each building rather than one Multibus I system per circuit as is the case for other Tevatron quench protection monitors. The software has been written in C for portability and flexibility for possible use with other magnet systems. Object oriented communications with the ACNET control system are made via the Token Ring network.

I. INTRODUCTION

When the new low beta quadrupoles were installed at the B0 and D0 straight sections of the Tevatron[1], the quench protection system was re-designed. Each low beta insertion now consists of five individual circuits. One of the five circuits includes a trim supply which requires that circuit be treated as two independent circuits.

II. HARDWARE

The quench protection monitor hardware is comprised of a standard VME crate with a 400 watt power supply, a Motorola MVME133a-20 processor board, a Formation FV1600 token-ring interface board and a four mega-byte ram board. In addition to the purchased boards, several in-house designed boards are used. These include three scaler boards a control board and a global functions board. The entire crate, as well as some supporting hardware, is powered by an uninterruptable power source which can supply 120 volts ac to the system for approximately 20 minutes.

The hardware external to the VME crate is the same hardware that is used for the rest of the Tevatron.[2] The voltage to frequency convertors were re-packaged to allow more channels per crate. The heaters in two of the circuits required ganging of heater firing units in order to supply the required energy. External current sharing resistors had to be added to the heater firing units in these circuits. Figure 1 shows the quench protection monitor and how it is connected to the external hardware.

The three scaler boards are identical. They are VME versions of the scaler boards used in the Multibus I systems. These boards have 30 channels each as opposed to the 40 channels on a Multibus I scaler board. For the low beta systems, 30 channels each allows each scaler to be dedicated to a specific type of voltage to frequency convertor. These being the +/- 10 volt, the +/- 200 milli-volt, and the +/- 100 volt range voltage to frequency convertors.

The control board is a digital I/O board that inputs status from and sends qpm status to the low beta power supplies. The heater firing units are also monitored and controlled by this card.

The global functions card is another digital I/O board which monitors and controls external systems such as the refrigeration system, the beam abort system, the correction element power supplies and the uninterruptable power source. The global functions card supplies the VMEbus interrupts which trigger the quench detection and protection software routines. The interrupts are synchronized by a phase locked loop which provides 60 Hz, 360 Hz and 720 Hz line-locked signals. The 60 Hz signal is used to trigger the quench detection software and the 360 Hz or the 720 Hz are jumper selectable to trigger the quench protection code which determines the levels output to the external hardware.

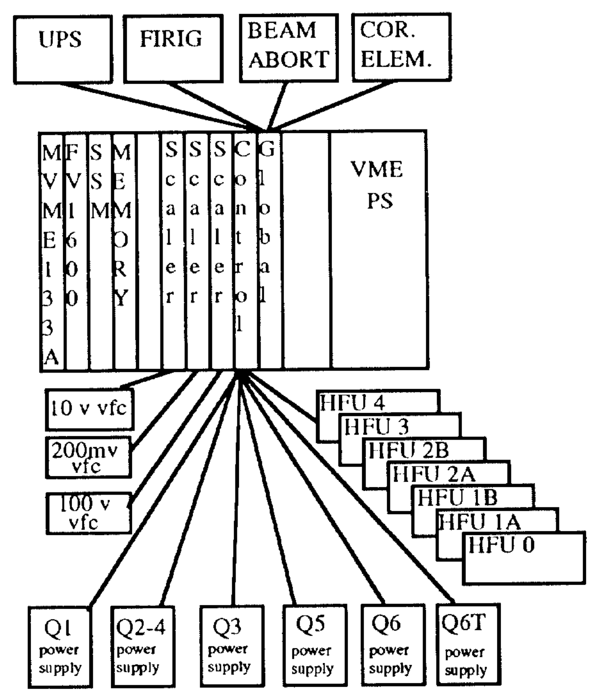

Figure 1. Low Beta Quench Protection System

III. SOFTWARE

The software includes both a purchased operating system and in-house code written in the C language. The actual quench detection and protection software run above the operating system as interrupt service routines which are unknown to the operating system. The communications software, Object Oriented Communications[3], and the interface to ACNET are comprised of tasks running under the auspices of the operating system.

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In order to make the system flexible, the number of circuits, quench detection units and quench protection units are defined at compilation time. A quench detection unit refers to the section of the circuit between voltage taps and a quench protection unit is the group of magnets whose heaters will be fired if a quench develops in any of it's quench detection units.

The actual algorithm used to determine if a quench has occurred is the same as used in the Tevatron and Switchyard quench protection monitors. A 'relative' di/dt value is calculated based on the assumption that the circuit is superconducting and all voltages are inductive. This 'relative' di/dt value is used to calculate the expected voltage for each quench detection unit. The actual value of the voltage is compared to the expected value. Any differences are assumed to be caused by a resistance. If the absolute value of the voltage difference is greater than 0.25 volts, a quench is detected. As an additional check, the current is monitored, the actual di/dt is calculated and compared to the 'relative' di/dt. If these values are not in agreement, the system will not allow the magnets to be powered.

The actions of the system are controlled by masks which can easily be configured to accomplish the required responses. Although there are basic functions that cannot be masked out, such as firing of heaters or de-energizing the circuit in the case of a quench. These masks are altered slightly depending on the operational mode of the Tevatron, collider or fixed target.

While operating, the quench protection monitor maintains a circular buffer of all status, voltages and currents that can be accessed in the event of a quench.

When the Tevatron is running in the fixed target mode, the magnets are re-configured in the tunnel. In order to facilitate the change-over from one mode to another, the proper masks and parameters are stored in files which can be downloaded to the quench protection monitors. The monitors default to the collider mode. To account for magnets that are disconnected in the fixed target mode, the inductance values and the power lead resistance values are set to zero for the missing magnets. In this way, the monitoring cables do not have to be disturbed.

IV. OPERATIONAL EXPERIENCE

The low beta quench protection monitors have been installed since November of 1990. The initial installation consisted of all circuits at B0 and only one circuit at D0. The fixed target physics run began July 16, 1991. This configuration remained until the end of the fixed target physics run in January of 1992. By the middle of April 1992, all of the remaining circuits had been installed and tested.

These systems have been running with very little downtime since the beginning of the present collider run.

IV. REFERENCES

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[2] R. Flora, J. Saarivirta, G. Tool and D. Voy, "The Energy Saver/Doubler Quench Protection Monitor System", IEEE Trans. on Nucl. Sci., Vol. NS-28, No. 3, pp. 3289-3291 (1981).

[3] L. J. Chapman, "Object-Oriented Communications", Proceedings of the 1989 IEEE Particle Accelerator Conference, Vol 3, pp. 1631-1632.