

SNS INJECTION AND EXTRACTION KICKER WAVEFORM VERIFICATION AND MACHINE PROTECTION*

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Abstract

The Spallation Neutron Source (SNS) injection and extraction kicker systems were designed by Brookhaven National Laboratory for SNS. The kicker control systems were integrated using EPICS and has been used for supporting SNS ring commissioning and now for SNS beam production operations. One of the major challenges for SNS operations is to control beam loss. SNS injection and extraction kicker waveform monitor system has been implemented to support SNS high power operation. In this paper we present a method for the kicker power supply waveform monitor system by using current available industrial technology and recent operation experiences.

INTRODUCTION

SNS injection system is comprised of eight kicker subsystems, four for horizontal and other four for vertical. Pre-calculated injection kicker waveforms are used to minimize average beam current and space charges. It is crucial to successful operations that all eight injection kicker power supplies will follow their waveforms in time within their predefined tolerances. A typical injection waveform has 2 ms rise, 1 ms flat top and 1 ms painting curve. Monitoring or verifying the 1ms waveform painting curves for all eight kickers will increase the quality of target beam, minimizing potential beam loss and avoiding potential machine damage. SNS extraction system consists of fourteen kicker subsystems. One of the fourteen kickers can be optionally turned off for normal operations. Their current firing waveforms are ensuring the accumulated beam to be extracted in time. SNS extraction current waveform has 200ns rising, 680ns flat top and 100ns tail curve. Verifying the rising and flat top waveforms will help operator to quickly identify which extraction kicker is malfunctioning and needed to be bypassed, and then readjust current waveform amplitudes for all other kickers to minimize machine downtime. In this paper we will present SNS injection and extraction waveform monitoring systems by using available industrial products.

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Waveform Inputs

The existing injection kicker control system uses

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YOKOGAWA high-speed data measuring station WE7000 systems. Two Channel and one million samples per second WE7275 digitizer is used for injection kicker waveform settings and read backs.

Waveform Mask Pass or Fail Test

LeCroy 64Xi DSO is used to perform waveform mask pass or fail test. The initial performance evaluation of the LeCroy DSO was tested by both the vendor [1] and the control group. It is necessary to configure the DSOs to optimize its performance for the P/F (Pass or fail) test:

- DSO performance optimized for analysis
- Keep sample rate down to 1k samples per second
- Turn off auto calibration
- Turn off display

Even with the above optimization configuration, the scope cannot guarantee 60 Hz response time 100%. But it does meet SNS operation requirement of minimum 30Hz performance to improve machine protections.

The original LeCroy DSO output action is a pulse from 1ms to 40-50ms wide. This would not be able to support SNS 60 Hz time frame. A new LeCroy XStream firmware was created for SNS to use a strobe rather than a pulse for the P/F output action.

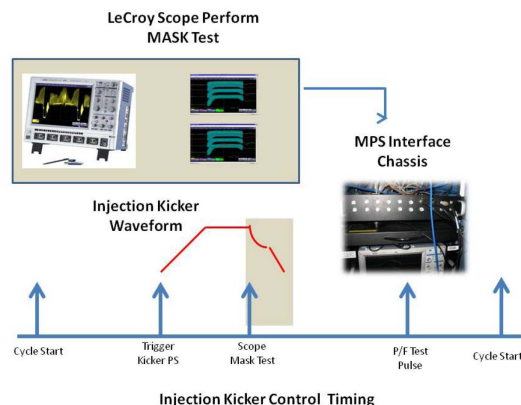


Figure 1: Injection kicker waveform monitor operator interface.

Timing and Machine Protection Interface

As shown in Figure 1, one event is added to trigger the MASK test scope to start its waveform verification and

optimize the scope usage. A MPS interface chaise is developed to link between MASK test scopes and the Machine Protection System system. The chassis has been designed to meet the following requirements:

- Pass trigger through the chassis until an input fault is received from either scope. On a fault, kill the trigger to the scopes so the waveforms can be captured.
- Generate an MPS latched fault on either fault condition, scope action output pulses to MPS interface chassis.
- Allow triggers to pass through the chassis whenever the trigger enable is set regardless of any current fault conditions. This will allow operators working on the system to make adjustments without any interruptions from the chassis.

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Monitor System Configuration

Four LeCroy 64Xi DSOs are configured to perform mask P/F test for the fourteen extraction kicker firing current waveforms. The scopes are configured to ensure performing each mask test cycle within 60 Hz, otherwise it will count as fault due to scope responding delay.

Four existing LeCroy scopes are used for operation remote monitoring via EPICS.

The extraction kicker MPS interface chassis is configured as following:

- Basic functionality – The MPS interface remains idle until a kicker fire pulse is received. It then monitors the mask scope inputs and records pass pulses. After receiving a cycle start pulse, it stops recording inputs and checks to see which of the mask scopes fired. If all inputs were present, the system returns to its idle state and waits for the next kicker fire pulse. If any one of the inputs are not present, the system generates an MPS auto reset (AR) fault for the appropriate channel and freezes the waveform monitor scope screens for 10 seconds. AR faults are held until a pass pulse is received.
- Chassis Inputs – Cycle start – Informs the MPS chassis that the current cycle is complete and stops the waveform monitor scan.
- Chassis Inputs – Kicker fire – Informs the MPS chassis to start scanning the mask scope inputs. Generated if a kicker charge event was produced in the previous cycle (normal 60 Hz operation)
- Chassis Inputs – Beam on – Informs the MPS chassis if the current cycle is a beam event cycle. This will release the waveform monitor screen freeze if the 10 second timeout has lapsed.
- Chassis Inputs – Bypass – Overrides the diagnostic screen freeze hold when a fault is present. This will be used to troubleshoot and set up the kickers. This

does not override or disable the functionality of the MPS system.

- Chassis Inputs – Waveform monitor inputs – These are the 4 BNC cables that are connected to the front of the chassis. The chassis monitors these inputs to determine if mask scopes fired.
- Chassis Outputs – Extraction kicker faults – There are 4 of these representing the 14 extraction kickers, one for each of the mask scopes. These are auto reset faults. These faults are help until a pass pulse is received from the mask scope.
- Chassis Outputs – Timing trigger okay – This is a failsafe mechanism that prevents us from relying on a system that is no longer available. The cycle start and kicker fire inputs are critical to the operation of this chassis. If either of these inputs are not present, the chassis will fail to operate correctly and will generate false MPS permissive signals. The signal present output will be faulted only if these input cables are removed or there is an error in the timing module that generates these signals. Both of these signals have independent counters that are reset when the input pulse is detected. If either counter successfully exceeds its threshold, an MPS fault is generated on this channel.
- Chassis Outputs – Diagnostic scope trigger – This is used to freeze the waveform monitor scope screens and allow users to identify which kicker misfired.

The figure 2 shows the timing configuration for the extraction kicker waveform monitor system.

Operation Evaluation

Extraction kicker waveform monitor system is implemented for failsafe. Table 1 shows that there are fault counts due to mask scope performance. Over 18 hours with 60 Hz operation, there were 57 faults in which two of them were the real faults for one scope while there were 87 faults in which 7 of them were real.

Table 1: Mask Scope Performance
60 Hz over 18 hours operation

	Caught by Scope	Fault Rate	Chatter Faults	Latched Faults
Scope 1 (EK1-4)	2 faults	51 u%	57	3
Scope 2 (EK5-8)	7 faults	180 u%	87	5
Scope 3 (EK9-12)	0 fault	0	14	0
Scope 4 (EK13-14)	0 fault	0	0	0

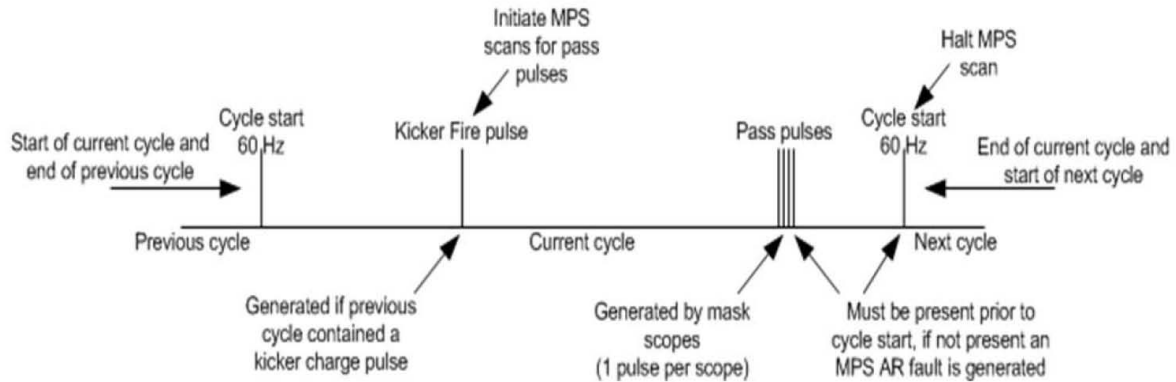


Figure 2: Timing configuration for the extraction kicker waveform monitor system.

DISCUSSION

Using industrial available products for SNS Injection and extraction kicker waveform monitoring systems have been implemented and installed for operations. The waveform monitoring will help minimizing beam loss and potential hardware damages. The hardware used for the system cannot meet 60 Hz requirement, thus the implemented system cannot give 100 % machine protection due to kicker power supply waveform faults. Two different approaches were used for the injection kicker waveforms and extraction kicker waveforms. Although the extraction kicker monitor system gives failsafe design and it is not applicable for operations. Due to many false interlocks of mask scope response delayed, operation is simply to bypass the system. On the other hand, the injection kicker waveform monitoring system does not give 100% machine protection. But it is functional for operation and is contributing its machine protection functionality to SNS machine operations.

FUTURE WORK

We are already evaluating other industrial products that can demonstrate 100 % protection performance. One is the Z-Tec scope [2] and other is the customized ADC board proposal [3]. We also look into VME ADC modules that have the sample rate that meets both SNS injection and extraction kicker waveform monitoring requirements.

ACKNOWLEDGEMENT

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