PRINCETON PLASMA PHYSICS LABORATORY

CRR_CHITID - CHIT RESOLUTION REPORT

RTC&P SHORTED TURN PROTECTION CHIT RESOLUTION REPORT

NSTXU_1-7-3-6-9_CRR_100

Rev. 1

Work Planning #: **3066**
Effective Date: **01/23/2020**
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National Spherical Torus eXperiment Upgrade

Chit Resolution Report For Shorted Turn Protections System

NSTXU_1-7-3-6-9_CRR_100 Rev 1

Prepared by: Greg Tchilinguirian, COG

Approved by: Yuhu Zhai, Project Engineer

Record of Changes

Rev.	Date	Description
0	10/2/2019	Initial
1	1/20/2020	Updated to include PDR CHITS, Peer Review CHITS

Chit Resolution Report:_____#NSTXU_1-7-3-6-9_CRR_100

Shorted Turn Protection CHIT Log

Review	CHIT	STATUS
Shorted Turn Protection CDR	STPROTECTCDR01	*CLOSED*
Shorted Turn Protection CDR	STPROTECTCDR02	*CLOSED*
Shorted Turn Protection CDR	STPROTECTCDR03	*CLOSED*
Shorted Turn Protection CDR	STPROTECTCDR04	*CLOSED*
Shorted Turn Protection CDR	STPROTECTCDR05	*CLOSED*
Shorted Turn Protection CDR	STPROTECTCDR06	*CLOSED*
Shorted Turn Protection CDR	STPROTECTCDR07	*CLOSED*
Shorted Turn Protection CDR	STPROTECTCDR08	*CLOSED*
Shorted Turn Protection CDR	STPROTECTCDR09	*CLOSED*
Shorted Turn Protection CDR	STPROTECTCDR10	*CLOSED*
Shorted Turn Protection CDR	STPROTECTCDR11	*CLOSED*
Shorted Turn Protection CDR	STPROTECTCDR12	*CLOSED*
Shorted Turn Protection CDR	STPROTECTCDR13	*CLOSED*
Shorted Turn Protection PDR	STPROPDR01	*CLOSED*
Shorted Turn Protection PDR	STPROPDR02	*CLOSED*
Shorted Turn Protection PDR	STPROPDR03	*CLOSED*
Shorted Turn Protection PDR	STPROPDR04	*CLOSED*
Shorted Turn Protection PDR	STPROPDR05	*CLOSED*
Shorted Turn Protection PDR	STPROPDR06	*CLOSED*
Shorted Turn Protection PDR	STPROPDR07	*CLOSED*
Shorted Turn Protection PDR	STPROPDR08	*CLOSED*
Shorted Turn Protection PDR	STPROPDR09	*CLOSED*
Shorted Turn Protection PDR	STPROPDR10	*CLOSED*

Shorted Turn Protection PDR	STPROPDR11	*CLOSED*
Shorted Turn Protection PDR	STPROPDR13	*CLOSED*
Shorted Turn Protection PDR	STPROPDR14	*CLOSED*
Shorted Turn Protection PDR	STPROPDR15	*CLOSED*
Shorted Turn Protection PDR	STPROPDR16	*CLOSED*
Shorted Turn Protection PDR	STPROPDR17	*CLOSED*
Voltage Measurement for the Shorted Turn Protection System Peer Review	VMSTPPR01	*CLOSED*
Voltage Measurement for the Shorted Turn Protection System Peer Review	VMSTPPR02	*CLOSED*
Voltage Measurement for the Shorted Turn Protection System Peer Review	VMSTPPR03	*CLOSED*
Voltage Measurement for the Shorted Turn Protection System Peer Review	VMSTPPR04	*CLOSED*
Voltage Measurement for the Shorted Turn Protection System Peer Review	VMSTPPR05	*CLOSED*
Voltage Measurement for the Shorted Turn Protection System Peer Review	VMSTPPR06	*CLOSED*

CHIT Resolutions

Review	ID	CHIT
Shorted Turn Protection CDR	STPROTECTCDR01	Reconsider the 1mS latency requirement. The system should be as fast as possible to limit fault energy, but not so fast as to trigger on noise, and need not be much faster than the response time of the power supplies.

Resolution:
This has been considered, the final requirements to respond to a detected fault hold at 1mS with sampling and processing in the 200us timescale.

Commented [1]: +gtchilin@pppl.gov

Please reference RD "NSTXU_1--7--3--6--9_RD_100" _Assigned to Greg Tchilinguirian_

Review	ID	CHIT
Shorted Turn Protection CDR	STPROTECTCDR02	Charlie's concern about targeting a RT computer system too much is valid. The algorithm evaluation and code generation Dan has done would still be very useful if code can also be generated that runs on a 'closed' DSP system. Other signal interfacing (MDS+ etc) would need to be addressed.

Resolution:
Multiple approaches were considered and the use of an RT computer was deemed preferable. The existing DCPS codebase, engineering staff and FPDP infrastructure lends itself to a simple solution using these existing (at PPPL), known technologies.

Review	ID	CHIT
Shorted Turn Protection CDR	STPROTECTCDR03	Could use raw Rogowskii in real-time algorithm

Resolution:
The system will use the Halmar signals and utilize a similar filtering design for the voltage measurement to maintain timing between the two measurements and filter hardware. This was a desirable feature of the final design to ensure pairs of signals are acquired with minimal temporal distortion.

Review	ID	CHIT
Shorted Turn Protection CDR	STPROTECTCDR04	We need to define what requirements we have on our voltage sensors clearly AND include as much as possible existing experience with what we have (Charlie mentioned that the existing ones drift a lot ...)

Resolution:
The voltage measurement hardware portion of the design has been replaced, after testing the system at the measurement points in the SDS cabinets to ensure the voltage measurements will meet design requirements.

Review	ID	CHIT
Shorted Turn Protection CDR	STPROTECTCDR05	Modeling needs to address 1-turn coupling between PF and TF

Resolution:
Data was obtained from Analysts CAD models, but I will likely want to use dedicated vacuum shots to assess the actual coupling. The algorithm doesn't have to change at all, it can include or exclude the coupling by changing numbers in the model. These shots are typical of the shots used to commission the machine and perform ISTP.

Review	ID	CHIT
Shorted Turn Protection CDR	STPROTECTCDR06	Consider how current direction and open circuit coils will be accounted for in the calculations. I think this could be done in a user interface without dedicated measurements.

Resolution:
Line positions will be read via EPICS to determine switch position and open circuit status prior to SOP. If these configurations are incorrect the algorithm will detect voltage or current where there should be none and declare a fault.

Review	ID	CHIT
Shorted Turn Protection CDR	STPROTECTCDR07	Consider use of a soft shutdown feature instead of Level 1 suppress/bypass, that might reduce the magnitude of induced current in shorted turns.

Resolution:
The additional complication of implementing a mechanism for a soft shutdown is substantial and the means to shut the machine down softly under different failure conditions is unknown. Therefore this is not a required function of the STP at this time.

Review	ID	CHIT
Shorted Turn Protection CDR	STPROTECTCDR08	Consider the digital transmission of voltages, line switch positions, and bus link positions from each SDS cabinet to STP point of utilization. This would avoid reliance on existing wiring, CAMAC, EPICS, etc. that is not sufficiently reliable for protection system.

Resolution:
The final design uses digital communication of line switch positions, existing Halmar Current measurements (in FPDP) and adds voltage measurements to the FPDP stream. EPICS will provide switch positions via CAMAC which, if missing or incorrect, will be detected by the protection algorithms and trigger a Level 1 Fault. These signals already exist via Ethernet or in the FCPC junction area, which is where the Real-time computer will be installed.

Review	ID	CHIT
Shorted Turn Protection CDR	STPROTECTCDR09	I have concerns about duplicate/overlaid handshake signals between (3) Systrans when using a fiber optic splitter. I recommend you contact the manufacturer about this configuration.

Resolution:
There will be a single fiber optic splitter installed in the final design of this system, with no additional systrans. The use of an SL240 installed in the real-time computer with a split fiber-optic signal has been in continuous use for operations since 2015 and has performed acceptably.

Review	ID	CHIT
Shorted Turn Protection CDR	STPROTECTCDR10	Explore possible simplification by measuring and transmitting voltage across coil (SDS output) terminals instead of measurements from each coil terminal to ground.

Resolution:
This measurement technique was explored and tested. The final design will measure each leg to ground using matched Ross Voltage Dividers, redundantly, and provide differential measurements to the real-time computer for processing.

Review	ID	CHIT
Shorted Turn Protection CDR	STPROTECTCDR11	Include provision to disconnect SDS voltage measuring system during coil hipot testing.

Resolution:
The voltage measurement system can be unplugged following previous procedures.

Review	ID	CHIT
Shorted Turn Protection CDR	STPROTECTCDR12	The System "A" approach uses existing FPDP parts. Will that impact our spares count, that are needed for DCPS and PCS? Consider whether System "A" could place DCPS at greater risk.

Resolution:
The Final design differs from the original “System A” design and reuses existing FPDP equipment already in operation. There are no effects on DCPS/PCS spares.

Review	ID	CHIT
Shorted Turn Protection CDR	STPROTECTCDR13	Should provide mechanism for getting alpha commands from PSRTC into STP to correct for drifts/offsets in voltage measurements.

Resolution:
Considered. Deemed out of scope for this protection system.

Review	ID	CHIT
Shorted Turn Protection PDR	STPROPDR01	Should the system be operational after EOP if current in the coils or plasma still exists? The implication is that it is not.

Resolution:
The system will continue to operate for a period that can be set through parameters in the STP parameter tree.

Review	ID	CHIT
Shorted Turn Protection PDR	STPROPDR02	Include an EPICS interface to provide status, fault (etc.) information from the STP in your final design.

Resolution:
An EPICS interface is included in the final design.

Review	ID	CHIT
Shorted Turn Protection PDR	STPROPDR03	Define in more detail the voltage sensors in the SLD and whether they should be communicated by tri-ax or an optical sensor.

Resolution:
The system will resemble the existing voltage measurement system but be redundant and use matched Ross Voltage divider units.

Review	ID	CHIT
Shorted Turn Protection PDR	STPROPDR04	There is a decision to be made between using the ROSS or FLARE voltage sensors recommend a peer review prior to FDR to address the decision. This is particularly related to the FLARE voltage sensor testing.

Resolution:
Peer review here was held along with an additional meeting to discuss this. The final design uses Ross Voltage Dividers instead of the FLARE design.

Review	ID	CHIT
Shorted Turn Protection PDR	STPROPDR05	DRP needs to be signed and filed. Prior to signing, please correct categorization to A1. Also, there was discussion of including the calculation related to splitting the signal as a proper calculation. Rather than just saying "Y", we are supposed to list the required calculations. We list Tech Specs & SOW for FDR. Are we really expecting both? Do we intend on preparing them for the FDR? If not, consider updating DRP accordingly.

Resolution:

A new categorization shee was generated with better granularity for components in the system. A1 components are the voltage measurement devices and filter/amplifier devices located in the SDS cabinets.

Commented [2]: +gtchilin@pppl.gov Please upload the revised DRP onto the dashboard. Thx
Assigned to Greg Tchilinguirian

Review	ID	CHIT

Shorted Turn Protection PDR	STPROPDR06	For Jim Corl - Almost certainly need line/ground switch status, so look at seeing if the data is usefully available at Rack 606.

Resolution:
Switch status is read from Rack 606 via EPICS. This information is used to configure the protection algorithms.

Review	ID	CHIT
Shorted Turn Protection PDR	STPROPDR07	When discussing calibration of the Voltage Sensors (which had last been calibrated some time ago), it was noted that their accuracy is not critical and they should be labeled "Indicator only". Please evaluate the proposed system for any measurement equipment whose accuracy is actually important, and ensure that calibration is properly managed & controlled.

Resolution:
New Voltage sensors will be procured as part of the final design. Calibration can be achieved at the amplifier prior to operations. Prior to each shot baseline subtraction will further prepare the protections system to measure in the event of drift.

Review	ID	CHIT
Shorted Turn Protection PDR	STPROPDR08	The system will require SQA form(s) and a cyber security evaluation.

Resolution:
Software is categorized as A3 and requires a categorization sheet to be submitted. Best practices dictate the use of version control, bug tracking and test procedures even though the categorization of the system is low risk.

Review	ID	CHIT
Shorted Turn Protection PDR	STPROPDR09	Determine whether the alpha signal feedback into FPDP is necessary for control purposes, or just post-shot fault/failure analysis. If it is the latter consider including data acquisition of this signal in an FCPC CAMAC replacement job (future).

Resolution:
The alpha signal measurement was deemed unnecessary for the final design of the system.

Review	ID	CHIT
Shorted Turn Protection PDR	STPROPDR10	Please plan to digitize the watchdog in something like a DTACq

Resolution:
The WDT and fault signals will be digitized using the DCPS JA digitizer. A visual indication in the junction are as well as an EPICS display will also indicate status remotely.

Review	ID	CHIT
Shorted Turn Protection PDR	STPROPDR11	Please document the intended test plan for the deployed configuration, in a means that checks all the critical things (latency, calibrations, links in shared memory, etc)

Resolution:
A detailed test plan, similar to OP779 will be generated prior to operation to ensure the system is fit for operational support.

Commented [3]: +gtchilin@pppl.gov The detailed test plan shall be discussed at FDR (may still not be completed at FDR) _Assigned to Greg Tchilinguirian_

Review	ID	CHIT
Shorted Turn Protection PDR	STPROPDR12	Suggest to have a peer review of your choice of voltage sensor BEFORE the FDR. This is a key component of the process, and you don't what to get into an avoidable argument by not getting buy-in before the FDR.

Resolution:
A peer review was held on this topic. A decision was made to utilize Ross voltage dividers in the final design.

Commented [4]: +gtchilin@pppl.gov Please upload Peer Review Result summary onto FDR dashboard. Thx _Assigned to Greg Tchilinguirian_

Review	ID	CHIT
Shorted Turn Protection PDR	STPROPDR13	The inclusion of the FG alpha archiving system is not yet demonstrated to have a specific benefit to this scope. Same with the soft shutdown links. Should demonstrate that it has some specific benefit before accruing that additional complexity and commitment.

Resolution:
These features have been deemed unnecessary for the functions needed to meet requirements.

Review	ID	CHIT
Shorted Turn Protection PDR	STPROPDR14	ASAP, lay out the cost/schedule coupling between Recovery and M&RP

Resolution:
All coupling between M&RP and Recovery have been severed.

Review	ID	CHIT
Shorted Turn Protection PDR	STPROPDR15	Input cost and schedule data specifically the coupling with the DITS/FIMM spares and dependencies

Resolution:
All coupling between M&RP and Recovery have been severed.

Review	ID	CHIT
Shorted Turn Protection PDR	STPROPDR16	Discuss with Tim (operations) on how the physical mechanism of resetting faults should be done. Do you want it resettable via software, or via hardware? For all kinds of faults?

Resolution:
Level 1 faults will be reset using the existing DCPS Junction area Hardware interface chassis.

Review	ID	CHIT
Shorted Turn Protection PDR	STPROPDR17	Determine usage of the ground/line switch measurements. How do you use this data? Do you need it sampled before shots or during shots? Talk to Jim Corl about the information. Then update requirements, including probably the SRD.

Resolution:
Line positions will be read via EPICS to determine switch position and open circuit status prior to SOP. If these configurations are incorrect the algorithm will detect voltage or current where there should be none and declare a fault.

Review	ID	CHIT
Voltage Measurement for the Shorted Turn Protection System Peer Review	VMSTPPR01	Please assess if the menagerie of current sensing technologies that are deployed have different phase shifts, etc. that may impact the use of those sensors in this application.

Resolution:
We will use the existing Halmar Signal Conditioners for this design. The voltage measurements will use a similar filter design as the Halmar units.

Review	ID	CHIT
Voltage Measurement for the Shorted Turn Protection System Peer Review	VMSTPPR02	The GNU high voltage divider differential input may experience high common voltage (up to 3kV) if one of the coil terminal is shorted to the ground. The rating of the differential amplifier (AD8479) is only +/- 600v. The circuit need to be designed to survive this kind of failure mode.

Resolution:
Ross Voltage dividers are used in the final design instead.

Review	ID	CHIT
Voltage Measurement for the Shorted Turn Protection System Peer Review	VMSTPPR03	Reconsider Ross Engineering in lieu of in-house design & fab. Existing Ross dividers are still measuring accurately and have a proven track record. The Ross system (dividers, matched amplifiers) are tested and calibrated as a complete system.

Resolution:
Ross Voltage dividers are used in the final design instead. Matched units will be procured to provide differential measurements.

Review	ID	CHIT
Voltage Measurement for the Shorted Turn Protection System Peer Review	VMSTPPR04	The AT should not be in control of the Test Mode in GNU Term Panel. Perhaps use a spare signal that is enabled when the Test Cards are plugged into the Hans Box.

Resolution:
An existing test signal will be used to determine mode.

Review	ID	CHIT
Voltage Measurement for the Shorted Turn Protection System Peer Review	VMSTPPR05	Consider providing buffered outputs of the WDT and fault signals to a d-tacq for independent recording.

Resolution:
These signals will be provided to the Junction Area Dtacq.

Review	ID	CHIT
Voltage Measurement for the Shorted Turn Protection System Peer Review	VMSTPPR06	For operational awareness, EPICS should be aware of the STP system status, preferably for several components. This could be through channel access or a hardware interface (an RTU digital input).

Resolution:
An EPICS interface is included in the final design.

Cognizant Individual:_____(sign and date)

Approver (*):_____(sign and date)

(*) For CDR and PDR the DRC, for FDR and after FDR the Main Approver (A-1: Chief Engineer, A-2 and A-3: DRC)
DRC =Design Review Chairperson