DESIGN REVIEW DOCUMENTATION – RESULTS – No: 1-1-3-4

Title: PF1CU&L Bus, PF4 Bus Final Design Review **CAT:** ■ A1 ☐ A2 ☐ A3 ☐

Type of Review: ☐ Peer ☐ CDR ☐ PDR ■ FDR

Cognizant Individual: D. Cai **Date of Review:** 7 February 2020

Review Board Members:	Invited Attendees:	Other Attendees:
Chairperson R. Ellis		
RE		
TA (*Subject*) *Name*		
TA (____)		
QA		
ESH		
Regulatory Compliance		

Items Reviewed:	Sat.	Unsat.	Comments or n/a if not applicable
Appropriate requirements identified	■	☐	
Development plans and schedules	■	☐	
Reg. compliance incl. USI/USID and NEPA	■	☐	
Disposition of CHITS from previous reviews	■	☐	
Calculations (all listed are signed and filed)	☐	☐	Checked, filing in process on 2/7
Cost objectives	■	☐	
Other review objectives addressed	■	☐	

SUMMARY OF RESULTS: Please see attached report

Disposition: [check one]

Acceptable

■ **Acceptable pending resolution of concerns**- CHITS identified above must be resolved prior to installation.

_____ **Incomplete** - Additional design work is required prior to another design review.

_____ **Unsuccessful** – Corrective actions must be taken and another review process must be initiated.

Design Review Chair Person Robert Ellis Digitally signed by Robert Ellis Date: 2020.02.19 08:15:05 -05'00' Date: _____

Cognizant Individual Acceptance Dang Cai Digitally signed by Dang Cai DN: cn=Dang Cai, o=PPPL, ou=Engineering, email=dcai@pppl.gov, c=US Date: 2020.02.19 08:33:18 -05'00' Date: _____

Distribution: Review Board Members, Operations Center, Responsible Engineer (RE), Cognizant Individuals, Project Manager, Project Director, relevant Technical Authorities (TAs), Chief Engineer (CE), Fire Protection Engineer, Attendees, QA, ES&H, Security, Requesting & Performing Dept. Head

PF1CU&L Bus, PF4 Bus Final Design Review Report

18 February 2020

Attendees

R. Ellis (Chair and Chief Engineer), J. Dellas (Power Systems TA), S. Gerhardt (Systems Integration and Research Operation), M. Kalish (COG, magnets), H. Wetzel (ES&H), A. Castaneda (QA), D. Loesser (VVIH RE and Mechanical TA), M. Smith* (MCS COG), S. Raftopoulos (Magnets RE), M. Safabakhsh (Manufacturing TA), P. Titus (Analysis TA), J. Mitchell (CAD), P. Dugan, Y. Zhai, S. Sheckman, D. Cai, A. Khodak, J. Winkelman, J. Fang, W. Blanchard, J. Dellas, A. Indelicato (DoE), W. Wang*, W. Que, C. Rana, M. Cropper, G. Swider, T. Stevenson

*remote connection

Executive Summary

The final design review of the bus bars was split into several parts. This review covered the bus bars and bus support structures for PF1C upper and lower, the PF4 hard and flex bus and supports, the PF1B water cooled power cable connection from the vessel to PCTS, the TF extension connection field fit-up, and the OH coax hard bus field fit-up. There were 25 chits, of which one was rejected. Seven pertained to analysis, six to drawing details, notes and appropriate signers, 4 to electrical. None were serious enough to prevent the design from proceeding to a conclusion. The review was deemed "successful pending resolution of concerns.

The review of the bakeout bus, originally to have been part of this review, was postponed to another date.

Introduction

The final design review of the inner PF coils in March 2018 included design improvements to the coil terminal supports. This review covers additional work on the supports, bus bars and their supports. The goal is to have a system of bus bars and supports that has acceptable stresses, and maintains the validity of the design assumption for the inner PF coils, and for the flex cable support at the end of each bus bar to provide integrity of the system.

Discussion

S. Raftopoulos and P. Dugan introduced the job and presented requirements and interfaces. D. Cai presented an overview of the design. He noted that the upper PF4 bus must have its connections loosened before bakeout, so that the vertical growth of the center column does not result in stresses being introduced into the coil leads. A general question related to the sensitivity stresses in the bus bars to the accuracy of installation was raised and was the subject of a chit.

S. Sheckman presented the design of the flex cables, and the OH coax bus and TF extension connection fit-up.

Y. Zhai presented the PF1C bus load and boundary assumptions, and A. Khodak followed with a presentation on the analysis. He noted that one of the plates in a bus support had a large chamfer that was not present in his analysis This concern was documented in a chit;

P. Titus presented loads and boundary conditions for the PF4 bus. Followed by an analysis presentation by J. Fang.

All of the analyses showed stresses within the allowable values.

D. Cai presented manufacturing and installation plans, along with cost and schedule.

Conclusion

The review was considered successful, pending resolution of concerns.

Summary of chits

Comment/Concern/Recommendation:	Review Board Comment:	Review Board Recommendation:
Ensure the "cancellation clamp" is grounded in the design documentation (this plays a role for all the cancellation clamps frankly)		Concur
Ensure that the electrical standoff of the cancellation clamp is adequate. The high-voltage SME had not reviewed it at the time of the review	Weiguo will evaluate	Concur
Ensure the the PF-4 disconnection requirement (and PF-5) is placed in the bakeout procedure.	Define disconnect	Concur
We committed to covering the terminals and sealing them with silicon boots . Do the terminal towers and bus reinforcements allow these boots to be installed?	Ensure installation is possible	Concur
For PF-1C, the details for constraining the flags within the lead support system need to be on the drawings; BoM and supporting notes.		Concur
PF1C bus suppport at can - the plate under the bus has a large chamfer. This is not what was analyzed The full area of this plate is probably needed. Redesign the plate so that it matches the analysis and has acceptable stresses.		Concur
Have Andrei review his old calculation and make sure the OH hard bus small changes are consistent with Andrei's old calculation		Concur
The installation of bus in the field shall result in slight differences from the details modeled and analyzed. Perform a sensitivity study of this designs ability to accommodate those differences. The results of the study can be implemented into the drawings as the allowable range of field-fit adjustment.		Consider
NSTXU_1-1-3-4_CRR_100, the Chit Resolution Report, must be fully signed in DMS.		Concur
Has the existing Pf4 hard bus, and the associated supports, that connects the lower and upper Pf4 coils been analyzed per SDC?	Slides shown this has been fully analyzed	Rejected
For the field fitted "bits and pieces" specifically, TF flag extension fit up parts, have these been analyzed? Have the parts been analyzed to bound the allowed range of possible sizes being specified on the drawings?	Project should consider the best way to resolve this before installation	Consider
Ensure the PSS configuration managed safe guards account for the new PF1B cable trays.		Concur
Please ensure that components (cables, trays, etc) are labelled properly in the field.		Concur
The details and notes on the prints must show how the conditions required by the analysis shall be met. This applies to any conditions where bonded/friction/slipping/gap-filling epoxies are important, such as the connections between flags, bus bar and their structural supports.		Concur
The flex cable dielectric withstand test at 9.1kV needs to be completed prior to the submission of the DAF for this work.		Concur
SR should be signing the bus drawings - those components are 100% magnets. The supports that tie to VV can be signed by DL.		Concur
On many (most) inner PF bus drawings, it is not indicated that the bar is brazed. On some drawings the notes state the brazing inspection requirements, but not the alloy which should be in the BOM		Concur
All supports and clamps should be reviewed for tracking distance to ensure there is enough margin to support the high-pot voltage requirement. I see some instances where there is line of site across a short surface. We may need to add Kapton barriers or other simple fixes to increase margins ie tracking distance. The distance as shown might be adequate but in these locations we must account for the possibility of surface contamination reducing the dielectric standoff.		Concur
Use belleville washers on bus flag connections		Concur
document / demonstrate the assumption that there is no cyclic loading on the bolts. Or, provide hardware fatigue life estimate / SF in the calculation.		Concur
Verify that the G10 / G11 parts are included in the analysis and stresses are within the allowable range. This includes the lead supports / interface in the coil.	Verify.	Concur
Not a chit against the design proper...the bus bar designs arei) qualified against the 96 scenarios, and ii) configured to pick up some vertical field. The first is allowed by the off-ramp in the GRD that allows designers to qualify against the 96 equilibria if they cannot design for loads up to the limits of the power supplies. Historically, the TF was considered the dominant source of bus bar loading, and DCPS limits on the TF were adequate to protect the bus bars. Recommendation: show that that the I_BusBar x TF load is dominant for the present designs with their odd "kinking" geometry. This is as simple as running again when the PF contribution is turned off. If the PF is a significant source of load, then it will be necessary to assess if the DCPS needs additional algorithms.	Not affect this design. But the project needs to decide	Concur
The assembly drawings for the components reviewed today should include the fastening details (bolts, washers, bellevilles, etc.) that are required to comply with the analysis		Concur
For tension perpendicular to the plies on G10 parts, compare the analysis results to the value obtained for unbaked G10 that was determined for the G10 compression ring.	compare to the test data	Concur
Ensure that connections of the water cooled bus to the CWS manifolds is in the Project baseline. I recommend simply including this as scope within the present control account (1.1.3.2), but in any case ensure it is someplace and has an owner.		Concur

National Spherical Torus eXperiment Upgrade

MAG-200129-YZ-01

TO: D. CAI
FROM: Y. ZHAI
SUBJECT: CHARGE FOR PF1CU&L BUS, PF4 BUS FINAL DESIGN REVIEW – Rev. 1

1 Introduction

The NSTX-U Recovery Project completed a final design review (FDR) for the inner PF replacement coils on March 30, 2018 that included significant design improvement to the coil terminal supports. The project also completed two preliminary design reviews (PDR-I & PDR-II) on the inner PF Bus on February 28, 2019, on bakeout BUS, the PF4 BUS support and remaining Bus scope on October 14 2019 respectively.

This FDR shall present the final design of BUS work scope including

- Inner PF 1C coil bus bars and bus support structures
- The PF4 hard and flex bus and supports
- PF1B water cooled power cable connection from vessel to PCTS
- The TF extension connection field fit-up
- The OH coax hard bus field fit-up

The flex cable support at the far end of the coil bus bars will also be evaluated to ensure sufficient structural integrity for the inner PF Bus bar system. The design review methodology will conform to the latest version of ENG-033 (Rev. 8), based on A1 risk classification.

2 Purpose

The purpose of this final design review (FDR) is to review final design of the PF 1C coil terminal support structure, the PF1C bus bars, and the bus support structures, including both upper and lower regions, as well as other BUS work scope listed above.

3 Requirements

- General Requirements Document, NSTX-U-RQMT-GRD-001-03.

- System Requirements Document for Magnet Systems, NSTX-U-RQMT-SRD-002-02.

- NSTX Structural Design Criteria, NSTX-CRIT-0001-02.

4 Scope

The scope of this FDR includes PF1C coil terminal supports, PF1C coil bus bar and bus support, the PF4 hard and flex BUS, the PF1B water cooled power cable job, TF extension connection job and the OH Coax BUS field connection job. Cost and schedule will be covered, and review of the manufacturing and installation of the bus, power cable, and supports will also be included.

5 Methodology

The FDR shall be conducted in accordance with existing PPPL procedure ENG-033 "Design Verification," supplemented by the participation of the NSTX-U Project Engineer.
The following are the FDR objectives/deliverables (as applicable):

- Review and verify that the final design satisfies all requirements and is ready for implementation.
- Verify resolution of chits from previous reviews.
- Verify that detailed analyses, calculations, and tests are complete and documented including calculation checking.
- Review and verify that the final product can be manufactured, inspected, assembled, stored, delivered, and installed reliably, safely, and cost effectively.
- Review and verify that appropriate documentation is available for producing the final product (e.g. drawings, installation procedures).
- Review and verify that procurement issues have been identified and resolved.
- Review and verify that appropriate test plans for the final product have been established.
- Review and verify that identification and control of items has been addressed.
- Review and verify any SAD/ASE considerations have been resolved.
- Review and verify that human factors are appropriately addressed in the design.
- Formally convey the design output for approval via the Design Approval Form (ENG-033 - Attachment 6).

Review materials shall be presented to the Design Review Committee and Project Engineer for acceptance, and then distributed to the review committee one week in advance of the review.

6 Review Committee

The Design Review Committee shall be constituted as follows. In case any persons are absent, the review may proceed at the discretion of the Design Review Chair (DRC) and NSTX-U Project Engineer (PE).

Robert Ellis	Design Review Chair and Chief Engineer
John Dellas	Power System TA
Stefan Gerhardt	Systems Integration and Research Operation
Michael Kalish	COG, Magnets
ES&H	N. Gerrish or H. Wetzel
Doug Loesser	VV+IH RE & ME TA
QA Representative	F. Malinowski or A. Castaneda
Mark Smith	VV+IH, SME
Steve Raftopolous	RE, Magnets
Mojtaba Safabakhsh	Manufacturing TA
Peter Titus	Analysis TA
John Mitchell	CAD Design

7 Agenda

The review shall be accomplished over one half day, scheduled for February 7, 2020, with the following preliminary agenda:

7-Feb-20	NSTX-U INNER PF BUS WORK PDR		
	Agenda		
Start	**Duration**	**Topic**	**Presenter**
9:30	5	Introduction	S. Raftopoulos
9:35	5	Requirements	P. Dugan
9:40	35	PF1C, PF4 BUS Design, PF1b power cable etc.	D.Cai / S. sheckman
10:15	10	PF1C Bus- Load and Boundary Assumptions	Y. Zhai
10:25	20	PF1C U&L BUS Analysis	A. Khodak
10:45	15	PF4 Loads and Boundary assumptions	P. Titus
11:00	20	PF4 BUS Analysis	J. Fang
11:20	15	Manufacturing & Installation Plan, cost & schedule	D.Cai
11:35	10	Chit Disposition	DRC
11:45	**Adjourn**		

cc:

L. Hill
W. Blanchard
D. Cai
G. Swider
A. Castaneda
J. Dellas
P. Dugan
J. Fang
R. Hawryluk
S. Gerhardt
M. Kalish
J. King – DOE
A. Indelicato – DOE
S. Rogan – DOE
F. Malinowski
N. Gerrish
H. Wetzel
W. Wang
A. Khodak
J. Mitchell
R. Ellis
Y. Zhai
J. Petrella
W. Que
S. Raftopolous
C. Rana
M. Safabakhsh
P. Titus
S. Weidner - PU
J. Winkelman
B. Sullivan – DOE
P. Johnson – DOE
D. Niemenski - DOE
J. Mitchell

PPPL QA
NSTX-U File

PFIC FDR Attendance

R. Ellis
P. Dugan
X. Zhai
S. Gerhardt
John Mitchell
S. Sheckman
P. Titus
M. Safabakhsh
D. Cai
A. Khodak
D. Loesser
J. Winkelman
J. Fang
W. Blanchard
J. Dolles
A. Indelicato DoE
H. Wetzel ES&H
A. Castaneda QA
M. Smith } Zoom
W. Wang }
W. Que
C. Rane
M. Cropper
M. Kalish
G. Swider
T. Stevenson