THE PREPARATION FOR THE COMMISSIONING OF CSNS ACCELERATORS*

S. Wang#, J. Peng, H. F. Ouyang, S. N. Fu
IHEP, Beijing, 100049, China

Abstract

The China Spallation Neutron Source (CSNS) is now under construction, and the beam commissioning of ion source will start from the end of 2013, and will last several years for whole accelerators. The commissioning plan for the CSNS accelerators will be presented, including the commissioning correlated parameters, beam instrumentation used in the commissioning, the goal at different commissioning stages. The development of high level application software will also be presented.

INTRODUCTION

The China Spallation Neutron Source (CSNS) is an accelerator-based facility. It operates at 25 Hz repetition rate with an initial design beam power of 100 kW, and is capable of upgrading to 500 kW[1]. CSNS consists of a 1.6-GeV Rapid Cycling Synchrotron (RCS) and a 80-MeV linac, which can be upgraded to 250-MeV for beam power upgrading to 500 kW. RCS accumulates 80 MeV injection beam, and accelerates the beam to the design energy of 1.6 GeV, and extracts the high energy beam to the target. The 1.6 GeV proton beam is transported through Ring to Target Beam Transport (RTBT) line onto the neutron target. The Table 1 shows the primary parameters of CSNS.

Table 1: The Main Parameters of CSNS RCS

	CSNS	Upgrade
Beam power (kW)	100	500
Repetition rate (Hz)	25	25
Target number	1	1
Average current (μA)	62.5	312
Proton energy (GeV)	1.6	1.6
Linac energy (MeV)	80	250

The construction of CSNS has been started in September 2011. The commissioning will start at the end of 2013. Starting from the ion source, the accelerators will be installed and commissioned sequentially.

THE COMMISSIONING SCHEDULE AND THE GOAL AT EACH STAGE

According to the commissioning goal, the commissioning can be divided into 3 stages: The first stage is from Oct. 2013 to Aug. 2017, to commission the low intensity beam to the target; The second stage is from Aug. 2017 to Mar. 2018 to increase the beam power to 10kW for official acceptance; The third stage is from Mar. 2018 to Mar. 2021 to increase beam power to the design goal of 100kW. The first stage is the most important for the commissioning. In the first stage, the front end, linac, LRBT, RCS, and RTBT will be brought into beam operation, and the primary beam parameters will be characterized with low intensity, and establish and validate the whole commissioning procedures which will be used for the high intensity normal operations. The study of various error effects on the beam, and the dependence of beam performance on various tuning parameters will be done. The study on the beam loss will be done, and the measurement of the beam losses to determine the threshold of beam loss for MPS will be also done at this stage. Table 2 shows the planned commissioning schedule. Table 3 shows the beam dump will be used in the commissioning.

Table 2: Planned Commissioning Schedule

Front end	Oct.18,2013-Apr.10,2014
RFQ,MEBT,DTL1	Jun.5,2014-Aug.27,2014
DTL2-4	Jun.302015-Nov.3,2015
LRBT+Linac	Nov.4,2015-Jan.6,2016
RCS	May13,2016-Mar.2,2017
RTBT	Mar.3,2017-Aug.24,2017
First beam on target	Aug.24, 2017
Beam power to 10kW	Aug.25,2017-Mar.3,2018
Beam power to 100kW	Mar.3,2018-Mar.3,2021

Table 3: Beam Dumps Used in the Commissioning

Beam dumps	Beam energy	Power limit
Linac-dump1	250MeV	4kW
Linac-dump2	250MeV	200W
Temp. dump	30MeV	160W
Inj-dump	250MeV	2kW
RCS-dump	1.6GeV	7.5kW

*Supported by National Natural Science Foundation of China (11175193)
#wangs@ihep.ac.cn

LINAC COMMISSIONING

Linac commissioning can be divided into 3 phases: MEBT, DTL-1 and DT2-4 commissioning. The MEBT will be commissioned with a temporary movable beam dump put at the end of MEBT. MEBT has all kind of beam instruments which will be used in the linac commissoning, also two bunchers which are RF components. The beam test in the MEBT is not only for itself, but will also contribute to the whole linac on the commissioning of beam instrument, control system, power supply and RF system.

In longitudinal tuning, we will find the RF set point of buncher cavities with a phase scan method, which will also be adopted in the RF tuning of DTL. The RF amplitudes of two bunchers are determined finally by the beam transmission rate at the exit of DTL-1. In transverse tuning, based on the measured beam parameters, calculate the emittance and Twiss parameters at the exit of RFQ, and then the quadrupole strength is set based on the calculated emittance and Twiss parameters. The orbit will be corrected to a proper value with BPMs and steering magnets.

In the second phase of linac commissioning, DTL-1 will be tuned before the installation of other three DTL tanks. In the DTL-1 commissioning, a temporary test beam line, called D-plate, will be adopted, which is consisted of BPM, BCM, FCT, EM(emittance measurement), wire scanner and a beam dump. D-plate will be installed just after DTL-1, and used for performing the necessary beam diagnostic for DTL-1 commissioning.

For longitudinal tuning, the RF set point of DTL-1 will be searched with phase scan method[2,3]. The tuning goal of the RF set point is 1deg in phase and 1% in amplitude. The phase scan curve obtained with a numerical model for the design RF set-point is adopted as the reference curve, and the reference curves is shifted to fit the measured phase scan curves under various RF amplitude settings. The deviation between the measured phase scan curve and the fitted phase scan curve is fitted using a 2nd order polynomial function with respect to the tank amplitude so as to find the optimum tank level. The accuracy of the RF tuning is determined by the phase scan step.

After the commissioning of DTL-1, the D-plate will be removed, and DTL2-4 will be installed together. The beam instruments in the LRBT will be used for the commissioning of the left three DTL tanks. The three tanks will be commissioned one by one. When the upstream tank is commissioned, the downstream tank will be set as transport line. The tuning procedure for each tank is similar to the DTL-1. Before the fine longitudinal tuning, only the linac-dump2 can be used, since there is no bending for beam to reach it. Due to the power capacity limit, the commissioning with linac-dump2 can be performed only with low beam power.

RCS AND BEAM TRANSPORT LINE COMMISSIONING

Two dumps at the end of straight section of LRBT and a dump at injection section will be used in the LRBT commissioning. The Table 4 shows the beam diagnostics in LRBT and RTBT. There is a debuncher in LRBT, and its RF set-point should be tuned firstly in the LRBT commissioning, and then the transverse tuning based on the design optics will be done. The optics model can be re-calculated and calibrated based on the measured emittance, twiss parameters and the beam profiles as constraints.

The beam instruments, BPMs, BCMs, and WSs will be commissioned, and then measure the beam energy, emittance, trajectory and optics. In the beginning, the beam can be tracked by both BPM and BLMs, and The transport efficiency will be measured by using BCMs. The beam orbit can be corrected by correctors to minimize the beam loss. The dispersion in LRBT can be measured by adjusting the linac energy via the accelerating phase of the last cavity. Beam based alignment for BPMs and quadrupoles offset are considered. Before injection into the RCS, chopping tuning will be performed.

There are two dumps which can be used in the RCS commissioning: Inj-dump and RCS-dump, as shown in Table 3. Table 5 shows the beam diagnostics in RCS.

Table 4: The Beam Diagnostics in LRBT and RTBT

Section	CT	FCT	BPM	BLM	FBLM	WS	WCM	MWPM
LRBT	2	3	20	28		7	3	5
RTBT	4		33	50	2	8		2
Inj. Dump	1		2	3	1			1
R-Dump	1		2	6	1			1

Table 5: Beam Diagnostics in RCS

	SCT	MCT	DCCT	FCT	WCM	BPM	BLM	FBLM	tune
RCS	1	1	1	3	2	32+3	72	9	2

For the injection beam commissioning, the injection beam is firstly directed to the injection dump by pulling out the main stripping foil, and with the second stripping foil, the beam will be directly transport the injection

ISBN 978-3-95450-122-9

dump. By using three Multi-wire Profile Monitors (MWPM) near the stripping foil, the position and angle of the injection beam can be measured, and also the twiss parameters of injection beam can be evaluated by three MWPMs and other profile monitors in LRBT.

The RCS will be commissioned firstly with DC mode and single shot pulse. The transverse secondary collimators can be used as beam dump. By using turn by turn BPM and BLM to track the beam, perform the storage of the first beam, and wall current monitor (WCM) can be used to measure the beam current. After the beam has been stored, the injection bump orbit need to be precisely re-tuned. By using one turn by turn BPM, with a single short mini-pulse injection beam (less than 150ns), the relative injection orbit height can be precisely measured. The precise measurement of relative injection orbit height is one of the most important issues in the injection commissioning.

For multi-turn injection, firstly, it can be performed with fixed injection point, and then the phase space painting will be performed first in one plane, and then in both plane. The painting beam will be extracted immediately after painting, and the painting beam distribution can be measured by using wire scanner in the RTBT beam line.

With the stored beam, closed orbit distortion, linear optics can be measured and corrected. Beam loss and collimation study should be carefully studied for high intensity and AC mode commissioning. The Debuncher parameters will be optimized according to the estimation of momentum spread and beam loss.

Based on the optimized DC mode with RF cavities, with the short injection pulse, AC mode commissioning can be performed. The lowest frequency will be set according to the measured energy of injection beam. Check the tracking among 5 families Q power supply and 1 family dipole power supply based on the tune and twiss parameter measurement. The COD and optics parameters will be measured during the different stage of a RCS cycle by ICA method using turn by turn BPMs. 8 cavities will be firstly independently commissioned with beam, and then commissioned together. For AC mode, the voltage curve should be optimized based on the beam.

Extraction will be commissioned for both DC and AC mode. The diagnostics in the RTBT line up to dump will be commissioned, and the extracting beam will be firstly directed to the RCS dump through the RDBT dump line. The kicker should be checked independently with small amplitude, and the timing of kicker should be adjusted. In the beginning, BLMs in RCS and RTBT will be the tool to track the extraction procedure, and the extraction condition will be established by tuning the timing and amplitude of kickers. The Interlock between RF phase and LEBT chopper will be checked, as well as the interlock between RF phase and extraction kickers. The emittance of extraction beam can be measured with wire scanners in RTBT.

For the injection beam commissioning, the injection beam is firstly directed to the injection dump by pulling out the main stripping foil, and with the second stripping foil, the beam will be directly transport the injection dump. By using three Multi-wire Profile Monitors (MWPM) near the stripping foil, the position and angle of the injection beam can be measured, and also the twiss parameters of injection beam can be evaluated by three MWPMs and other profile monitors in LRBT.

THE DEVELOPMENT OF HIGH LEVEL COMMISSIONING SOFT WARE

The application software for CSNS accelerators is developed based on the XAL, and now some basic XAL applications have been transferred to CSNS. Many applications in XAL have been re-written or modified to meet the special requirement of CSNS, especially the RCS related part. Up to now, the DTL tuning related software, including the phase scan and the transverse optics calculation have been completed; the optics calculation and matching, orbit measurement and correction and twiss parameter measurement for transport line have been done; For RCS, the software for injection, the optics and COD measurement and correction, RF system control, collimator control and etc, are now available. All the application software will be finally move to the scheme of Open XAL.

SUMMARY

The commissioning plan for CSNS accelerators is given, and the detailed schedule for commissioning is also described. The goal at different commissioning stages, and some key commissioning procedures for each part of accelerators are considered and presented.

ACKNOWLEDGMENT

The authors would like to thank CSNS colleagues for helpful discussion, also thanks to the experts of J-PARC RCS commissioning team for sharing with us the commissioning experience of J-PARC accelerators .

REFERENCES

[1] Wang S, An Y W, Fang S X, et al. An overview of design for CSNS/RCS and beam transport. Scientific China Physics Mechanics & Astronomy 54 (Suppl 2): s239-s224, 2011.

[2] M Ikagami et al. RF Amplitude and Phase Tuning of J-PARC DTL. Proceedings of PAC07, Albuquerque, New Mexico, USA.

[3] SHEN Guo-Bao et al. Tuning of RF amplitude and phase for the drift tube linac in J-PARC. CPC(HEP&NP), 2009, 33(7): 577-582.