INDIAN PARTICIPATION IN LHC, SPL AND CTF-3 PROJECTS AT CERN, SWITZERLAND

V. Bhanage, J. Dwivedi, A.K. Jain, P. Khare, S. Kotaiah, P.K. Kush, Abhay Kumar, S.S. Prabhu, A.M. Puntambekar, A. Rawat, V.C. Sahni#, A. Sharma, R. Shridhar, Purushottam Shrivastava, G. Singh, Raja Ramanna Centre for Advanced Technology, Indore, India,
R.K. Sadhu, Bhabha Atomic Research Centre, Mumbai, India

Abstract

India has contributed to the construction and commissioning of CERN's most ambitious particle accelerator project the "Large Hadron Collider" (LHC) and is now engaged in other activities, namely, CTF 3 and LINAC-4. The contributions to LHC span from hardware, software, expert manpower support for evaluation of some of the LHC sub-systems and commissioning support of various subsystems of LHC. India has developed and supplied a total of 7080 Precision Magnet Positioning Systems (PMPS) Jacks for supporting Cryo-dipole magnets of LHC, 1146 Superconducting Corrector Magnets (MCS), 616 Superconducting octupole-decapole correcting magnets (MCDO), 5500 Quench Heater Power Supplies(QHPS), 1435 Local Protection Units (LPUs) etc., for LHC. With the background of these contributions to CERN's satisfaction, India was invited to participate in CERN's upcoming Advanced Accelerator Projects, like, Superconducting Proton LINAC, SPL and Compact Linear Collider Test Facility, CTF 3. The present paper describes the highlights of the past, ongoing and future collaboration activities.

INTRODUCTION

CERN has started commissioning world's biggest particle accelerator the Large Hadron Collider (LHC) located over the Swiss-French border about 100m below ground. It would be colliding protons, each with 7 TeV energy during end 2007-2008 and will later collide lead nuclei, each of 1150 TeV energy. Indian involvement in LHC began in 1996. Earlier, after informally working for many decades with CERN, India formally signed a cooperation agreement in 1991 which was then followed by a protocol (signed in 1996) that led to Department of Atomic Energy's various laboratories to participate in the construction and utilization of LHC. The protocol provided a framework to deliver hardware and expert manpower envisaging an 'in kind' Indian contribution valued at 34 million Swiss Francs (i.e. US $25 million at 1994 rates). This was later raised to 60 MCHF under an agreement signed between DAE and CERN. Half of the value of this 'in kind' contribution is treated as India's contribution to LHC and other half is credited to 'Indian Fund' which was created to provide support to our scientists for their stay at CERN and also to meet essential expenses in foreign exchange required for some of the contributions. The lead DAE lab for this collaboration is RRCAT, Indore. After successful completion of LHC related contributions, CERN invited India to join in its Advanced Accelerator Projects like Super Conducting Proton LINAC (SPL) and Compact Linear Collider Test Facility CTF-3. For this an additional protocol has been signed between Prof. Robert Aymer, Director General, CERN and Dr. Anil Kakodkar, Chairman AEC, India. This envisages additional contributions up to 5 MCHF on similar lines as done before for LHC contributions.

CONTRIBUTIONS TO LHC

The in-kind contributions that DAE committed is described in detail elsewhere [1][2] and a summary of some of these is given in Table 1. All the equipments, components and devices have been designed, developed, tested and supplied to CERN and accepted.

Table 1: Major Contributions to LHC

Sr.	Details of Indian Contributions	Qty.
1	50000 litres Liquid Nitrogen tanks.	2
2	Superconducting corrector magnets i) Sextpole (MCS) ii) Decapole and Octupole (MCDO)	 1146 616
3	Precision Magnet Positioning System (PMPS) Jacks	7080
4	Quench Heater Protection Systems (QHPS)	5500
5	Integration of QHPS units into racks	6200
6	Control electronics for circuit breakers of energy extraction system	70
7	Local protection units (LPU)	1435
8	SC Dipole magnet tests/measurements, expert support in Man years	100
9	LHC Hardware Commissioning of Cryogenics, Power converters, Protection systems, Controls. Man years	20
10	Data management software upgrade, Data analysis software/documentation projects	41 Man years eq.
11	Development of JMT-II software	
12	Software development-slow control of Industrial Systems of LHC	
13	Design and calculations for Vacuum system for beam dump line	
14	Analysis of cryo-line jumper and magnet connections	

The items listed in table 1 were pursued with the help from different units of DAE with RRCAT acting as nodal

#vcsahni@cat.ernet.in, vcsahni@magnum.barc.ernet.in

agency. RRCAT was involved with (1), (2), (3) (7), (8), (10), (13) & (14); BARC was involved in(10), (11), (12); BARC and Electronics Corporation of India Ltd (ECIL) were associated with (4), (5), (6) and (7); BARC, VECC, IGCAR and RRCAT, provided necessary skilled engineers and physicists for (8). BARC, RRCAT and ECIL are providing expert manpower support for (9). A brief description of some important items listed in table 1 is given below:

Superconducting corrector magnets (MCS and MCDO

The main dipoles of LHC are equipped with sextupolar (MCS) and decapolar (MCD) superconducting corrector magnets. Each decapole corrector also has an octupolar insert (MCO), and together these are designated as MCDO. Each corrector magnet consists of a superconducting coil assembly, glass fibre slit tube, steel lamination, aluminum shrinking cylinder for pre-compression of coils, end plates for connection, parallel resistor for magnet protection and a magnetic shield also acting as a support. Fig 1 shows picture of finished MCS and MCDO assemblies before dispatch.

PMPS-jacks

The various cryo-magnets need to be precisely positioned in the tunnel to ensure proper beam trajectories of particles. The dipole magnet assemblies, each weighing more than 32 tons with a length of 15 m, need to be positioned with a precision of 50 μm all along the 27 km length. Jacks have to be capable of accommodating LHC tunnel slope of 1.4%. The main specifications of the jack are: (a) range of movement (i) in X–Y phase ± 10 mm (in both directions simultaneously), and (ii) in Z direction ± 20 mm; (b) load capacity 32 MT, and (c) maximum operating torque for lateral movement to be less than 60 Nm in nominal realignment operation. A total of 7080 units were made by the Indian industry and supplied to CERN under the supervision of RRCAT. Fig. 2 shows a picture of the PMPS jacks ready for shipment to CERN.

Quench Heater Protection Systems (QHPS)

The LHC superconducting dipole and quadrupole magnets are powered with current up to 13 kA. All superconducting magnets require protection in case of quench (resistive transition) or other failures. The main dipole is equipped with quench heater strips on magnet coils and cold bypass diodes. When the quench is detected (via a floating-bridge detection of voltage build-up above a certain threshold value across magnet coils), the protection system will power the quench heater strips and distribute the energy evenly in the entire magnet. Fig. 3. shows a picture of QHPS integrated racks.

Local Protection Units

These electronic devices detect quench occurring on the LHC superconducting magnet system and is made of local quench detector and the acquisition and monitoring controller put together in a 3U, 19″ crate. The local quench detector is attached to an LHC superconducting magnet and activates the respective protection systems in case a resistive transition occurs. Fig 4 shows a picture of the local protection units.

Expert Manpower for Magnetic Tests and Measurements

The LHC cryo-dipoles, quadrupoles and corrector elements required testing as part of a QA plan at super fluid helium temperatures of 1.9 K, as well as at room temperature (warm) at dedicated test stations. These involve cryogenic tests, power tests, quench behaviour analysis, protection test, precise magnetic measurements at injection and high fields, and warm measurements. The SM18 Hall at CERN was the home for conducting all such evaluations, where several test stations were installed for dipoles (MB test-station based on twin rotating units and long shaft), quadrupoles (SSS test-station using automated scanner and LTD with single harmonic coil and single stretched wire system) and two benches for warm measurements. Teams of Indian specialists worked at SM18 hall and performed complete tests and measurements on full series produced magnets.

PARTICIPATION IN LINAC-4 OF SPL

RRCAT has designed an all-solid state klystron bouncer modulator for 1MW klystron for 3MeV RFQ of LINAC-4. A prototype is being built at RRCAT. RRCAT submitted three designs 1) All solid-state modulator with active compensation using a fast acting power supply. 2) All solid-state bouncer compensated modulator. 3) Conventional line type modulator. After intensive discussions between RRCAT and CERN teams, scheme 2 was agreed for prototype development and scheme 1 would be incorporated later by changing the lumped bouncer with an active power supply for droop compensation by feedback loop. Table 2 and figure 5 give salient features of the modulator.

Table 2: Specifications for modulator for LINAC-4

Parameter	**Design Targets**
Klystron modulator type	Bouncer
High Voltage pulse amplitude	-10kV to –110 kV
Pulse width, 70% to 70 % of pk.	800 □sec
Minimum Flat top available	600□sec
Maximum current during pulse	24A
Pulse repetition rate	2 Hz
Acceptable voltage drop	≤ 1.0 %
Allowed ripple on flat top	≤ 0.1 %
Rise time/fall time	<100 μsec
Arc energy dissipated in klystron	<10J

PARTICIPATION IN CTF 3

Some items for collaboration were identified based on CERN’s requirement. These are summarized in table 3. Design of TL-2 is nearly over and three prototype dipole vacuum chambers have been built and qualified. Fabrication of dipole magnets has been initiated.

Table 3: Items for contributions to CTF 3

Description	Requirement
CTF 3 control system Software	5 Man months
Optics Design of TL-2	Design
Dipole Vacuum chambers for TL-2 Straight vacuum chambers (Round and racetrack profile)	5 Quantity based on optics design
Dipole Magnets for TL-2 Nominal Field 1.3 Tesla	5

Figure 1: MCS & MCDO

Figure 2: PMPS jacks.

Figure 3: Integrated QHPS.

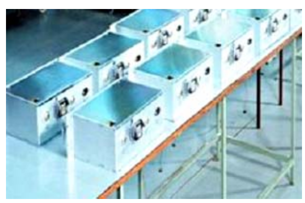

Figure 4: LPUs.

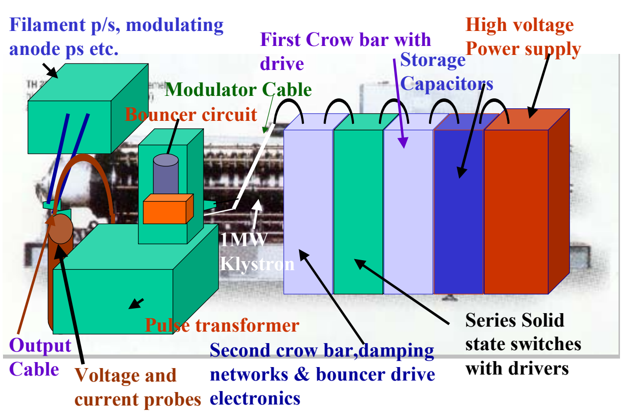

Figure 5: Prototype solid state modulator schematic.

Figure 6: Prototype dipole vacuum chamber for TL-2.

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