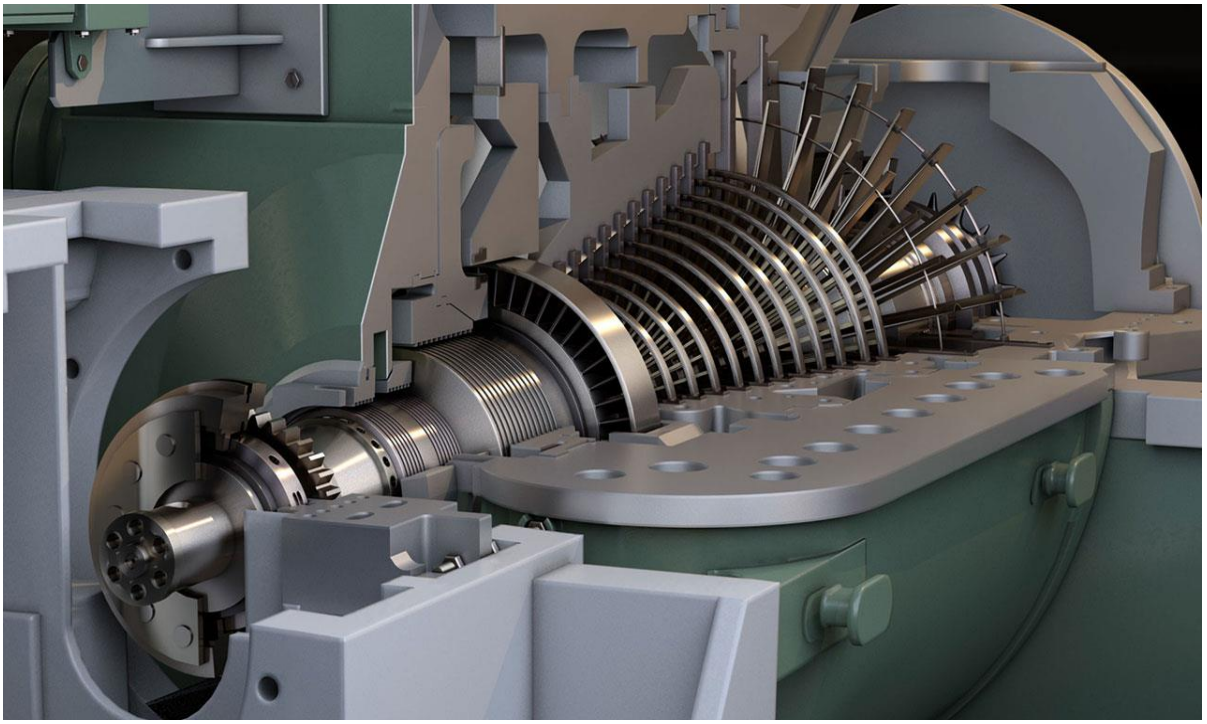
Review of Post R&M Experience in O&M from Pilot R&M Interventions in Thermal Power Stations in India



Prepared By:

WAPCOS Limited

Under

Technical Assistance to CEA for Addressing Barriers to Energy Efficient R&M of Coal Fired Generating Units

Under

India: Coal Fired Generation Rehabilitation Project

(March 2017)

CENTRAL ELECTRICITY AUTHORITY

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List of Abbreviations

AHP	Ash Handling Plant
AOH	Annual Over Hauling
AOP	Auxiliary Oil Pump
APC	Auxiliary Power Consumption
APH	Air Pre Heater
BSEB	Bihar State Electricity Board
BFP	Boiler Feed Pump
BHEL	Bharat Heavy Electricals Ltd.
BoP	Balance of Plant
BTG	Boiler, Turbine & Generator
C&I	Control & Instrumentation
CEA	Central Electricity Authority
CEP	Condensate Extraction Pump
CERC	Central Electricity Regulatory Commission
CHP	Coal Handling Plant
CPRI	Central Power Research Institute
CW	Cooling Water
DCS	Distributed Control System
DEH	Digital Electro Hydraulic
DESH	De Super Heater
DM	De-Mineralized
DPR	Detailed Project Report
EE R&M	Energy Efficient Renovation & Modernization
EPC	Engineering, Procurement and Construction
ESP	Electrostatic Precipitator
FD	Forced Draft
GCV	Gross Calorific Value
GoI	Government of India
GRP	Generator Relay Panel
GSECL	Gujarat State Electricity Corporation Ltd.
GT	Generator Transformer
HPGCL	Haryana Power Generation Corporation Ltd.
HP Turbine	High Pressure Turbine
HVAC	Heating, Ventilation and Air Conditioning
HT	High Tension
ID	Induced Draft
IP Turbine	Intermediate Pressure Turbine
JV	Joint Venture
KBUNL	Kanti Bijlee Utpadan Nigam Ltd.- JV of BSEB & NTPC Ltd
kCal	Kilo Calorie
kW	Kilo Watt
kWh	Kilo Watt hour
LE	Life Extension
LE&U	Life Extension & Uprating

LLD	Liquid Level Detector
LP Turbine	Low Pressure Turbine
LT	Low Tension
MoP	Ministry of Power
MOU	Memorandum Of Understanding
MPPGCL	Madhya Pradesh Power Generation Company Ltd.
MSPGCL	Maharashtra State Power Generation Company Ltd.
MU	Million Units
MW	Mega Watt
NA	Not Available
NO_x	Nitrous Oxides
NTPC	National Thermal Power Corporation Ltd.
O&M	Operation & Maintenance
OEM	Original Equipment Manufacturer
PFC	Power Finance Corporation
PG	Performance Guarantee
PSPCL	Punjab State Power Corporation Ltd.
PLF	Plant Load Factor
R&M	Renovation & Modernization
RLA/CA	Residual Life Assessment / Condition Assessment
SCC	Specific Coal Consumption
SOC	Specific Oil Consumption
SO_x	Sulphur Oxides
SPM	Suspended Particulate Matter
SWAS	Steam and Water Analysis System
TG	Turbo Generator
TOR	Terms of Reference
TPS	Thermal Power Station
UPRVUNL	Uttar Pradesh Rajya Vidyut Utpadan Nigam Ltd.
WBPDCL	West Bengal Power Development Corporation Ltd.

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Executive Summary

The performance of thermal power stations gets deteriorated over the years due to the ageing of the equipment and variation in the quality of inputs for power generation mainly the coal quality. Renovation & Modernization of such old thermal power stations becomes necessary in order to restore their performance in terms of output, reliability, availability, ease of maintenance, addressing the coal quality and other generic deficiencies in the power equipment. After implementation of the R&M works, it become essential to evaluate the performance of the rehabilitated units with respect to the target values for Renovation & Modernization. The evaluation is also important for assessment of the benefits accrued as well as establishing the techno-economic aspects of the R&M project.

Under the World Bank financed "Coal Fired Generation Rehabilitation Project", CEA has implemented the "Technical Assistance Project for Addressing the Barriers to EE R&M of Coal Fired Generating Units in India" and appointed WAPCOS, as a consultant, for the study on "Review of Experience from Pilot R&M Interventions in Thermal Power Stations in India" with the objective of sharing of experience mainly in procurement, implementation and improvement in performance parameters in R&M projects taken up in India. The review of experience in operation & maintenance of the rehabilitated thermal power stations has been one of the core activities of the above project to assess the benefits accrued as well as analyze the problems and challenges faced.

The unit-1&2 of Ukai TPS, unit-1&2 of Amarkantak TPS, unit-9&10 of Obra TPS, unit-3&4 of GNDTP Bathinda, unit-1 of KBUNL Muzaffarpur, unit-7 of Barauni TPS, unit-5 of Bandel TPS and unit-6 of Koradi TPS have been covered for reviewing post R&M experience in operation. WAPCOS experts visited these designated thermal power stations to collect necessary data/information. During such visits, the experts interacted with the concerned project authorities and collected the data on Power Generation, PLF, APC, SCC, SOC, Heat Rate for atleast three years prior to start of R&M and for atleast 6-12 months after the commissioning of the unit. The feedback obtained from the members of the Task Force on promotion of R&M in meetings and the Workshop has been incorporated by WAPCOS in the report.

It is observed that in all the units covered under the study, there has been increase in gross output and the rated capacity has also been restored. Also, there has been reduction in Auxiliary Power Consumption as well as significant reduction in Specific Oil Consumption after the R&M in all the units covered under the study. There has been improvement in the Heat Rate in the range of 2.59% to 31.59%. While there has been improvement in the performance parameters, but due to specific problems like excessive vibration and high temperature of turbine bearings, some units had to be run on reduced loads. Similarly, in some cases, full load could not be achieved without running extra BFP and CEP resulting into increased Auxiliary Power Consumption. In most of the cases, units took considerable time in

stabilization and giving desired performance. Further, it is observed that the units where R&M of Electro Static Precipitators has been done, the units have been able to meet the new stricter norms of SPM levels of 100mg/Nm^3.

PG Tests are not usually conducted after commissioning of the units as a performance check after undergoing R&M. In case of both units of Ukai TPS, PG test could not be conducted as units did not achieve rated capacity of 120MW. For Amarkantak TPS, PG test could not be conducted as R&M works were carried out by large number of firms/contractors and the same was not under their scope. Similarly, the PG test could not be conducted for the units-9 & 10 of Obra TPS as some works such as TG Auto Loops, SLDC, Burner Tilt Mechanism and Cooling Tower Fans have not yet commissioned. Also, there is axial shift problems in both the units. For Muzaffarpur TPS, PG test has not yet been conducted since BHEL has not submitted revised turbine PG test/demonstration. However, the PG tests have been conducted at unit 3&4 of Bathinda TPS and unit 5 of Bandel TPS.

At GNDTP, Bathinda, there were frequent joint leakages in Boiler area specifically in Economizer Banks. In order to reduce such frequent leakages, during R&M of Boiler 100% radiography of joints at site was done instead of present practice of 10% only as per the practice. This helped in improving the availability and generation of plant and also reduction in Specific Oil Consumption as frequent shut down of the units reduced.

Adaption of good O&M practices is of utmost importance to sustain the performance of the rehabilitated thermal power station. It is essential to adhere to Annual Maintenance Schedule strictly to avoid deterioration in condition of machines/ equipment and follow best practices in O&M after implementation of R&M at the units.

The report highlights the learning and experiences in the post-R&M performance of the thermal power plants covered under the study. These learnings and experiences captured through the study would encourage the power utilities for implementation of the R&M projects and address the problems and inefficiencies at their thermal power stations.

Chapter-1

Introduction

1.1 Introduction

The total installed capacity of India was 302,087.84 MW as on 31st March, 2016, out of which major share of 185,172.88 MW (61.29 %) is contributed by Coal based thermal power stations. This includes old thermal units commissioned way back in 1970s or even earlier which have already outlived their useful life and also those commissioned in early 1980s.

The following Tables give the status of Power Supply Position in various Regions of the country during the period from April-2015 to March-2016. Despite the installed capacity of more than 3 lakhs MW, there have been shortages in the Peak Demand and energy.

Table: 1.1 Peak Demand and Peak Met (April-2015 to March-2016)

S. No.	REGION	PEAK DEMAND	PEAK MET	Surplus(+)/Deficit (-)	
		MW	MW	MW	%
i	Northern Region	54474	50622	-3852	-7.1
ii	Western Region	48640	48199	-441	-0.9
iii	Southern Region	40445	39875	-570	-1.4
iv	Eastern Region	18076	17972	-104	-0.6
v	North Eastern Region	2573	2367	-206	-8.0
	ALL INDIA	**153,366**	**148,463**	**-4,903**	**-3.2**

Source: Central Electricity Authority (CEA), Lakshadweep and Andaman & Nicobar Islands are stand-alone systems, power supply position of these, does not form part of regional requirement and availability

It is observed that there was Peak Deficit in all the Regions ranging from 0.6% to 7.1%. The deficit in Northern, Southern and North Eastern Regions was remarkably high compared to other Regions.

Table: 1.2 Power Supply Position (April-2015 to March-2016)

S. No.	REGION	REQUIREMENT	AVAILABILITY	Surplus(+)/Deficit (-)	
		MU	MU	MU	%
i	Northern Region	340,488	324,021	-16,467	-4.8
ii	Western Region	346,650	345,848	-802	-0.2
iii	Southern Region	288,004	283,473	-4,531	-1.6
iv	Eastern Region	124,608	123,635	-973	-0.8
v	North Eastern Region	14,487	13,736	-751	-5.2
	ALL INDIA	**1,114,235**	**1,090,713**	**-23,522**	**-2.1**

Source: Central Electricity Authority (CEA), Lakshadweep and Andaman & Nicobar Islands are stand-alone systems, power supply position of these, does not form part of regional requirement and availability.

While efforts are being made to develop maximum capacity through Central/State Power Sector Undertakings, large capacity additions through Private sector is also envisaged. Though there is full effort both at State and National level to develop new power projects, the R&M of old thermal units is also a cost effective option to bridge the gap in the power supply in the country.

1.2 Renovation & Modernization (R&M)

The objective of Renovation & Modernization (R&M) of thermal power plants is to equip the operating units with latest modified & augmented technology equipment/systems with a view to improve their performance in terms of output, reliability, efficiency and availability, reduction in maintenance requirements, ease of maintenance and minimizing inefficiencies. The R&M Programme is primarily aimed at Generation sustenance and overcoming problems such as rise in Heat Rate, Specific Coal Consumption & Auxiliary Power Consumption and reduced Gross Generation & PLF etc. The Life Extension (LE) Programme is meant for operation of the plant beyond their original Designed Life, after carrying out life assessment studies of critical components.

R&M Programme was initiated in 1984 as a centrally sponsored programme during 7th Plan and the programme continued during the two Annual Plans 1990-91 & 1991-92. The R&M works continued during the 8th & 9th Plan. However the same could not be sustained during 10th Plan.

Central Electricity Authority (CEA) has prepared a National Perspective Plan for execution of Renovation & Modernization (R&M) and Life Extension (L.E.) works at various State owned Thermal Power Stations in the country. The document in this respect was released by Honorable Minister of Power on 14.12.2009 on the occasion of Energy Conservation Day. The above said Perspective Plan provides for rehabilitation of the old thermal power units with an objective of Efficiency Enhancement, Life Extension, Up-rating and reduction in Greenhouse Gases, emissions by through modification and technology up-gradation. The table gives out the status of R&M and Life Extension up to 11th Plan Period.

Table 1.3: Renovation and Modernization (R&M) and Life Extension Programme (LEP) from 7th Plan onwards till 11th Plan

S. No.	Five Year Plan	No. of Units	Capacity (MW)	Additional Generation Achieved MU/Annum	Equivalent MW*
1	7th Plan	163	13570	10000	2000
2	8th Plan (R&M) (LE)	198 (194) (4)	20869	5085	763
3	9th Plan (R&M) (LE)	152 (127) (25)	18991	14500	2200
4	10th Plan (R&M) (LE)	25 (14) (11)	3445	2000	300
5	11th Plan (R&M) (LE)	72 (59) (13)	16146	5400	820

Source: Quarterly Review Report-Renovation and Modernization of Thermal Power Stations (January-March; 2016), CEA,

**Equivalent MW has been worked out assuming PLF prevailing during that period.*

For the 12th Plan, 70 units with total capacity of 12066 MW for L.E. works and 65 Units with a total capacity of 17301 MW for R&M works have been identified as reflected below.

Table 1.4: Renovation and Modernization (R&M) and Life Extension Programme (LEP) for 12th Plan (2012-2017)

S. No.	Category	No. of Units Identified	No. of Units Achieved	Capacity Identified (MW)	Capacity Achieved (MW)
1	LE	70	18	12,066	2131.76
2	R&M	65	11	17,301	2060.50
3	Total	135	29	29,367	4192.26

Source: Quarterly Review Report-Renovation and Modernization of Thermal Power Stations (January-March; 2016), CEA.

1.3 Coal Fired Generation Rehabilitation Project

The World Bank has financed the "Coal-Fired Generation Rehabilitation Project-India" for demonstrating Energy Efficiency Rehabilitation & Modernization (EE R&M) at coal fired generating units through rehabilitation of 640MW of capacity across three States- West Bengal, Maharashtra and Haryana. The project would also try to address the critical barriers to large scale Energy Efficiency R&M in India. The project is funded through IBRD Loan of USD 180 Million and GEF grants of 45.4 million USD out of which 7.5 million USD have been earmarked to technical assessment/studies. The project has two components viz.

a) Component-1: Energy Efficiency R&M Pilot Projects
b) Component-2: 7.5 million USD have been earmarked for Technical Assistance to address Critical Barriers to EE R&M. The sub-components for the technical assistance program (Component 2) would cover
   i) Support for design of Energy Efficient R&M projects
   ii) Support for implementation of demonstration of EE R&M investments funded under Component-1 of the project
   iii) Support for addressing barriers to implement EE R&M projects in India
   iv) Support for strengthening of institutional capacities of the generation utilities and other relevant sector entities

1.4 Technical Assistance Project for Addressing Barriers to Implementation of R&M in India

Under the sub-component (iii) of the component-2 (Technical Assistance) around US$ 1.1 million of GEF Grants are being made available to provide technical support to CEA aimed at addressing barriers to implementation of R&M in India. This component was to be implemented through the Central Electricity Authority through appointments of Consultants including Implementation Support Consultant (ISC) to carry out following studies.

i) Review of Institutional Capacity and Implementation of Capacity Strengthening Interventions at CEA
ii) Reduction of barriers to R&M interventions in thermal power plants in India
iii) Developing markets for implementation of R&M scheme in thermal power stations in India
iv) Review of experience from Pilot R&M interventions in thermal power stations in India

CEA engaged WAPCOS Ltd on 23.07.2012 for undertaking study on "(iv) Review of experience from Pilot R&M interventions in thermal power stations in India". The objective of the study is sharing of experience mainly in procurement, implementation and improvement in performance parameters in Pilot R&M projects and other R&M/LE projects taken up during 11th plan and 12th plan.

The study covered the following activities.

a) Review of Procurement Experience including preparation of DPR, Bidding documents, etc.
b) Review of R&M Implementation Experience
c) Review of Experience in Strengthening of O&M Practices
d) Review of Post-R&M Experience in O&M
e) Dissemination of Learnings from Pilot R&M Interventions

1.5 Objective of the Assignment

The objective of the study is to gather the Post R&M experience of units which have undergone R&M. The experience would give the details about the performance of these units in respect of various important parameters and output, as compared to the target values. In addition, it will also bring out major problems and challenges faced by TPS and how they were able to solve the same. In the report all the above aspects are highlighted which would help the other power plants which are planning to go for R&M of old units in future, this would help and guide them in saving time and money.

1.6 Scope of Work of the Assignment

Review of Post - R&M Experience in O&M

a) To review and share the Post - R&M Experience in O&M after the plant has been in operation for a considerable time (say about six months) after completion of R&M works at the Thermal Power Stations as mentioned in Annexure III of Appendix-I. The review includes Post -R&M review of the operational performance of the generating units where R&M interventions have been undertaken till eight months before the scheduled timeline for submission of Draft Final Report and indicate the improvements in their operational performance.
b) To list out the problems/challenges faced in O&M of Thermal Unit after implementation of the R&M interventions and suggest suitable measures for further improvements in the units.
c) To make visits to listed Thermal Power Stations for the purpose of review of the Post-R&M experience in O&M.
d) Based on the review of O&M experience, to prepare a report on Post R&M experience in O&M at the listed thermal power stations for the purpose of sharing the experience for future R&M units.

Under the assignment, the following thermal power units have been considered for review of Post R&M experience in O&M.

Table 1.5: List of TPS considered for Review of Post R&M Experience in O&M

S. No.	Unit No	Capacity (MW)	Name of Thermal Power Station (TPS)/Utility
1	1& 2	2x120	Ukai TPS
2	1 & 2	2x120	Amarkantak TPS
3	9 & 10	2x200	Obra
4	3 & 4	2x110	Bathinda TPS
5	1	1x110	Muzaffarpur TPS
6	7	1x110	Barauni TPS
7	5	1x210	Bandel TPS
8	6	1x210	Koradi TPS

Chapter-2

Approach and Methodology

Post R&M Experience at 8 number of TPS of Pilot R&M Projects is reviewed. The Terms of Reference as per RFP are placed as Appendix-I. The Check List/Questionnaire prepared was supplied to the Project Authorities as per Appendix-III. The Check List/Questionnaire filled with the available data/information by them for further scrutiny & examination. Based on this, an analysis/review was carried out. The Team conducted the Analysis and Review of various aspects of Post R&M experience in O&M as required under RFP.

WAPCOS Experts visited the Thermal Power Stations to collect and compile the relevant Data/Document for review and analysis relating to the Thermal Power Stations. The following procedure was adopted by WAPCOS for execution of the assignment.

i. Site visits to Thermal Power Stations
ii. Interactions with the concerned Project Authorities and collection of relevant data/ information.
iii. Preparation of Report on Review of Post R&M Experience.

2.1 Review of Post R&M Experience in O&M

- The following aspects both before and after execution of R&M works were looked into and Pre and Post R&M data/information of designated units was collected and included in the report:
  - Gross Generation
  - PLF
  - Auxiliary Power Consumption
  - Specific Oil Consumption
  - Specific Coal Consumption
  - Heat Rate
  - SPM level
  - SO_x level
  - NO_x level
  - Cost of Generation
- Any problems/challenges encountered in O&M of the Thermal Power Plant after R&M works identified and analyzed for improvement.
- Recommended suitable steps to be taken for further improvements.
- Prepared a report on Post R&M experience in O&M for sharing the experience for future R&M projects.

The review covers unit post R&M experience in O&M, performance achieved, problems/challenges faced etc. by the thermal power stations.

2.2 Site Visits to Thermal Power Stations

List of Units considered for Review of Post R&M Experience in O&M for Pilot R&M projects for interaction with concerned project authorities and collection of relevant data/information, is given below:

Table 2.1: Visits to different TPS

S. No.	Unit No	Capacity (MW)	Name of Thermal Power Station (TPS)/Utility	Dates of Visits
1	1& 2	2x120	Ukai TPS	28th to 31st October 2015
2	1 & 2	2x120	Amarkantak Extension TPS	4th to 5th March 2013 & 21st to 25th September, 2015
3	9 & 10	2x200	Obra	22nd to 25th November 2015
4	3 & 4	2x110	Bathinda TPS	18th to 21st October 2015
5	1	1x110	Muzaffarpur TPS	26th to 28th November 2015
6	7	1x110	Barauni TPS	28th September to 01st October 2016
7	5	1x210	Bandel TPS	28th to 30th January 2013, 05th to 09th October 2015 & 03rd to 05th August 2016
8	6	1x210	Koradi TPS	21st to 23rd March 2013

A questionnaire was also circulated to the concerned thermal power stations for getting additional data/information regarding post R&M experience in O&M, which has been incorporated in the report.

2.3 Dissemination of Learning from Pilot R&M Projects and other R&M Projects:

In order to disseminate the learning and experiences WAPCOS in association with CEA conducted a workshop in Delhi on 3rd February 2017 which was attended by authorities from various utilities and firms like CERC, World Bank, WBPDCL, HPGCL, MSPGCL, NTPC, PSPCL, UPRVUNL, GSECL, MPPGCL, KPCL, RRVUNL, OPGC, BHEL, KBUNL and ABPS Infra Ltd.

Chapter-3

Post R&M Experience in O&M

Post R&M in O&M Experience study was carried out by visiting, interacting and collecting relevant data/information from the concerned Thermal Power Plant authorities of eight power stations of Pilot R&M Projects listed in previous chapter. A Check List/Questionnaire prepared at the initial stage was supplied to the Project Authorities for collecting the available data/information in the form of Annexure-III. WAPCOS Experts visited all the Power Stations listed under the study. The Team conducted the analysis and review of various aspects of project which broadly covered performance achieved, and identifying the areas where the actual problems were faced after R&M in O&M. The questionnaire broadly covered:-

a. Project name & capacity of the plant, date of start/completion of R&M works
b. Different performance parameters viz. Gross Generation, APC, PLF, SOC, SCC, Heat Rate etc.
c. Problems and challenges encountered in O&M after R&M and their remedial measures adopted

3.1 Unit# 1 & 2 (2x120 MW) Ukai Thermal Power Station, GSECL, (Gujarat)

A. Background of the Project

The Ukai Thermal Power Station is located near Ukai Dam on Tapi River in Tapi District of State of Gujrat. It is a coal based power station and it is operated by Gujarat State Electricity Corporation Ltd. There are two units of 120 MW each (Unit no. 1 & 2), two units of 200 MW each (Unit no. 3 & 4) and one unit of 210 MW (Unit no. 5) with a total installed capacity of 850 MW. All the above units are of BHEL make.

Commissioning dates of unit no. 1&2 are 19.03.1976, 23.06.1976 respectively. Both the units had completed their useful life of 25 years and were not operating at rated capacity and their PLF was also low with less efficiency. Both the units were in need of performance improvement and life extension particularly considering deterioration in coal quality, turbine problems, boiler problems, lower collection efficiency of ESP. The machines were operating at low PLF of 56.5% and with higher station heat rate.

CEA identified Ukai TPS unit 1&2 for R&M and LE Programme during 10th Plan. The contract was awarded to BHEL for carrying out comprehensive Residual Life Assessment (RLA), Condition Assessment (CA), Life Extension (LE) study and Performance Evaluation Test (PET) of 2x120MW units. RLA, CA and LE study of unit 1&2 was completed by BHEL during forced outage from 01.08.2003 to 30.04.2004 for unit-1 and during capital overhauling from 27.02.2003 to 17.06.2003 for unit-2. Final report of RLA/LE study was submitted by BHEL for both the units in March, 2003.

Based on RLA, CA, LE study & PET recommendations, the scope of work had been concluded through protracted discussions/interaction with GSECL Engineers/Officers of P&P department, Generation department and site engineers by BHEL. The major R & M works of unit no. 1 & 2 were carried out from 6.9.2006 to 24.02.2008.

B. Brief Scope of R&M Works

The scope of work for carrying out renovation and modernization of major packages are as under.

a. Boiler & auxiliaries:
Replacement of water wall tubes, economizer coils/tubes, super heater tubes etc. were included in this package was done.

b. Turbine & auxiliaries:
Replacement of turbine bearing nos. 1 to 7, replacement of inner and outer casing of HP turbine, replacement of rotor of IP and LP turbines, replacement of cartridges of BFP and replacement of CEP pump was done.

c. Generator:
Stator coil were rewound with Class F insulation and slip ring assembly was replaced.

d. Balance of Plant:
Fire detection system was installed across the units, up-gradation by installing new pumps in fuel oil station, replacement of air compressors, installation of new HVAC system, up-gradation of ash handling system, water system, water treatment plant, make-up water system and coal handling plant.

e. Electrical:
Replacement of 6.6kV VCB circuit breakers used for operation of HT motors.

f. Control & Instrumentation:
Replacement of old control system with new maxDNA Distributed Control System (DCS) supplied by BHEL.

C. Target for Key Performance Parameters

Based on RLA/LE study recommendations, discussions and negotiations, R&M and LE activities were finalized for achieving rated capacity generation of 120MW, Boiler Efficiency of 85.5%, Turbine Heat Rate of 2122 kCal/kWh, ESP outlet dust emission level of 125mg/Nm^3, plant availability of 85% for first year and life extension post R&M by 15-20 years, modernization of C&I by state-of-art DDCMIS.

Table 3.1: Design Parameters of Unit-1 of Ukai TPS

Parameter	Design Value	Target Value	Value Achieved
Turbine Heat Rate (kCal/kWh)	2061.95	2122	NA
APC (%)	9.0	NA	10.85 (2009-10)
SCC (kg/kWh)	NA	NA	0.88 (2009-10)
SOC (ml/kWh)	1.5	NA	12.83 (2009-10)
Boiler efficiency (%)	85.5	85.5	77.10
Turbine Efficiency (%)	2061.95	NA	NA
SPM (mg/Nm^3)	150	125	129.78

Table 3.2: Design Parameters of Unit-2 of Ukai TPS

Parameter	Design Value	Target Value	Value Achieved
Turbine Heat Rate (kCal/kWh)	NA	2122	NA
APC (%)	9.0	NA	11.46 (2010-11)
SCC (kg/kWh)	NA	NA	0.74 (2010-11)
SOC (ml/kWh)	1.5	NA	8.088 (2010-11)
Boiler efficiency (%)	85.5	NA	NA
Turbine Efficiency (%)	2061.95	NA	NA
SPM (mg/Nm^3)	150	125	149.39

D. Performance Parameters

Improvement in the operational performance can be gauged from performance parameters achieved after execution of R&M works which are given in the following paras/Tables. Unit-1 R&M works carried out from 06/09/2006 to 24/05/2008 (20 Months). Unit synchronized on 24.05.2008.

Table 3.3: Ukai Unit-1 Performance Pre and Post R&M

Parameters	Pre R&M			Post R&M		
	2004-05	2005-06	2006-07	2008-09	2009-10	2010-11
Gross Generation (MU)	285.35	573.23	219.78	157.886	532.732	694.32
PLF (%)	27.15	54.53	20.91	24.53	50.68	66.05
APC (%)	10.85	8.91	12.87	14.46*	10.85	11.46
SOC (ml/kWh)	6.4	1.02	1.02	66.81*	12.83	8.088
SCC (kg/kWh)	0.67	0.69	0.71	0.54	0.88	0.76
Heat Rate (kCal/kWh)	2765	2879	2978	2793	2813	2995
DM Water Consumption (m^3)	88640	148284	60466	102066	130313	132561
Coal Consumption (MT)	192602	397785	157901	141309	365114	520823

**The values of APC and SOC recorded during 2008-09 are abnormally high because of the fact that the Unit was commissioned on 24.05.2008 after R&M and was under stabilization.*

Table 3.4: Ukai Unit-1 Environmental Parameters and Outages

Parameters	Pre R&M			Post R&M		
	2003-04	2004-05	2005-06	2008-09	2009-10	2010-11
SPM (mg/Nm^3)	124/175	128/90.28	90.58/96.33	97.29	129.78	149.39
SO_x (mg/m^3)	26/18	45.87/36	22.75/19.67	43.25	53.94	42.66

NO_x (mg/m^3)	41/1.2	3.8/3.4	4.3/3.2	1.42	2.08	1.09
Forced Outage (%)	5	20	23	61	62	61
Planned Outage (%)	0	0	2	1	0	1

Unit 2 R&M works carried out from 12.08.2008 to 24.2.2010 (18 Months). Unit synchronized on 24.02.2010.

Table 3.5: Ukai Unit 2 Performance Pre and Post R&M

Parameters	**Pre R&M**				**Post R&M**		
	2004-05	**2005-06**	**2006-07**	**2008-09**	**2009-10**	**2010-11**	**2011-12**
Gross Generation (MU)	517.57	569.59	477.02	199.586	22.061	694.32	739.06
PLF (%)	49.24	54.18	45.38	18.99	2.1	66.05	70.11
APC (%)	10.49	9.38	10.94	14.73	21.64*	11.46	10.27
SOC (ml/kWh)	3.4	3.28	3.43	6.61	58.27*	8.08	1.032
SCC (kg/kWh)	0.66	0.68	0.71	0.72	0.56	0.74	0.734
Heat Rate (kCal/kWh)	2723	2876	2990	2893	2786	2995	2809.7
DM Water Consumption (m^3)	156870	179335	137927	124708	31119	172815	NA
Coal Consumption (MT)	345181	392784	342779	144207	12399	498985	NA

**The values of APC and SOC recorded during 2009-10 are abnormally high because of the fact that the Unit was commissioned on 24.02.2010 after R&M and was under stabilization.*

Table 3.6: Ukai Unit#2 Environmental Parameters and Outage

Parameters	**Pre R&M**			**Post R&M**		
	2005-06	**2006-07**	**2007-08**	**2010-11**	**2011-12**	**2012-13**
SPM (mg/Nm^3)	90.58/96.33	146.77/161.95	123.72/105.03	149.39	141.93	124
SO_x (mg/m^3)	22.75/19.67	33.91/33.71	26.95/28.59	42.66	81.92	89
NO_x (mg/m^3)	4.3/3.2	4.46/4.28	3.68/5.37	1.09	1.11	8.23
Forced Outage (Numbers)	27	36	20	54	22	34
Planned Outage (Numbers)	0	3	0	0	1	1

E. Experience in O&M after R&M

Following observations were made after running the units for a considerable time after R&M:

i. Generation level of 120 MW not achieved in both units.
ii. To achieve the Generation level of 120MW, it was required to run two NASH pumps, all three BFPs & two CEP, which resulted in increased in auxiliary power consumption.
iii. Vibrations of TG Bearing No. 6 & 7 of unit no.1 remained high.
iv. All the parameters of unit-1 & 2 improved except Heat Rate, SOC and maximum load respectively.

F. Problems /Challenges faced in O&M

Unit- 1 & 2 of Ukai TPS faced some problems in operation & maintenance after completion of R&M works. Unit# 1 R&M works were carried out during the period 06/09/2006 to 24/05/2008 (about 24 Months) and following problems were faced during post R&M operation:

Table 3.7: Problems faced in Ukai Unit#1

S. No.	Problems /Challenges faced
i.	TG bearing no.3 - Temperature remained high
ii.	Generator bearing numbers 6H/6V and 7H/7V vibrations remained high
iii.	Drum level cannot be maintained with two Boiler Feed Pumps [BFPs] at Generation level of 120MW. All three BFPs are required to run for 120MW unit load.
iv.	Deaerator level cannot be maintained with one CE Pump. Both CEPs are required to operate simultaneously to maintain De-Aerator level. The design parameters like steam pressure (126 kg/cm^2) are not reachable with two BFP and one CE Pumps running simultaneously

Unit # 2 R&M works were carried out during the period 12.08.2008 to 24.2.2010 (about 18 Months) and following problems were faced during post R&M operation:

Table 3.8: Problems faced in Ukai Unit#2

S. No.	Problems /Challenges faced
i.	Up to 114MW load two BFPs are required to run but to achieve the rated load of 120MW all three need to run simultaneously
ii.	Up to 114MW load one NASH pump is required to run but to achieve the rated load of 120MW both the pumps need to run simultaneously
iii.	Up to 114MW load one CE pump is required to run but to achieve the rated load of 120MW both the pumps need to run simultaneously
iv.	Continuous Blow Down (CBD) opened during normal operation because of higher presence of Silica content than the permissible limit in main steam

G. PG Test

PG test of both the units is still pending because the units are yet to achieve their rated capacity i.e. 120MW load on continuous basis. The above mentioned problems also are the cause of non-conduction of PG test. Also there are some issues between utility and OEM which were not shared. The performance of both the units kept on decreasing since 2011-12

and therefore, the units were subsequently retired in July, 2016 (unit-1) and year 2015-16 (unit-2) onwards, respectively. Based on the bad experiences of 120MW sets of Ukai TPS, major R&M of other 120MW units of GTPS have been dropped by GSECL.

H. Reasons for Satisfactory/Unsatisfactory Performance after R&M

It is very difficult to procure spares for O&M from OEM since these equipment have now become obsolete. The problems and challenges faced in O&M after R&M were the main reasons for unsatisfactory performance of both the units after R&M.

I. Overall Comments

For unit 1 gross generation and PLF was increased after R&M, all other parameters were more or less same as their Pre R&M values. Although it was noticed that the DM water consumption remained low for higher gross generation. The forced outages of the units increased after undergoing R&M. Similarly, for unit 2 the gross generation, PLF, APC, SOC and SCC had deteriorated.

3.2 Unit 1&2 (2x120MW) Amarkantak Extension Thermal Power Station, MPPGCL, (Madhya Pradesh)

A. Background of the Project

Amarkantak Thermal Power Station has an installed capacity of 450 MW. The first unit (120MW) was commissioned in November, 1977 and the second one (120MW) in May, 1978. The water for the plant has been procured from the nearby Sutna Nala Dam which is constructed on the Sone River and spread across 700 acres (2.8 km^2). The coal for the plant has been procured by rail from the mines of South Eastern Coalfields Limited.

Unit# 1

No DPR and feasibility reports were prepared. Only RLA study was taken as basis for R&M works. The date of start of R&M work is not available from the data provided but it has been mentioned that after completion of works the rolling of turbine was carried out a number of times but it could not be synchronized due to high eccentricity and vibrations in HP turbine. Hence, unit was stopped on 20.09.2010. In view of the above, capital over hauling work of TG of this unit was given to M/s. NASL and work was started on 10.11.2010. The work was finished on 24.03.2012 and unit was synchronized on 11.04.2012.

Unit# 2

The date of start of R&M work was 29.07.2009. The R&M work was completed on 11.09.2010 and unit was synchronized on 26.08.2010.

Both the units i.e. unit-1 & 2 were under forced shutdown. Unit-2 was under forced shutdown since 30th April, 2014 due to abnormal turbo-visory parameters. Unit-1 was under forced shutdown since 12th January, 2015 due to fire accident leading to failure of TG sets.

B. Brief Scope of R&M Works:

Work was split into following four main packages which were further subdivided into a number of small packages for different parts/components i.e. TG and its associated auxiliaries. All these works were carried out during the period 2004 to 2011.

i. R&M works of Boiler and Auxiliaries:

a. Dismantling of existing, Erection & commissioning of newly supplied Fabric Expansion Joints of Air and Flue Gas Ducts.

b. Erection Testing & Commissioning of various high and low pressure motorized valves.
c. Replacement of Economizer Coils, Secondary Superheater Coils, Superheater Top Bank, Reheat Coils Bottom Bank, Cage Bypass and Cage Enclosure.
d. Complete overhauling of Mills along with replacement.
e. Dismantling of existing Dampers and Erection, Commissioning & Testing of new Flap type Dampers.
f. Complete removal of old APH tube block and Installation & Commissioning with associated work of Air Preheater.
g. Repairing and strengthening of steel structure of Coal Bunker house, Boiler Mill and ESP area of PH II.

ii. R&M works of TG and its associated Auxiliaries:

R&M and overhauling of TG and its associated auxiliaries

iii. R&M works of Electrical Auxiliaries:

a. Dismantling, Erection, Testing & Commissioning including civil work of 6.6 kV switch gear
b. Erection and Commissioning of numerical relays for Motors, Generator Transformers and Station Transformers
c. Erection, Testing & Commissioning of 6.6 kV SF_6 Breakers

iv. R&M works of Instrumentation and Control:

Supply, erection, testing and commissioning of control and instrumentation.

C. Target Values of key Parameters

Following are the target values preset by the utility for achievement. The designed values were not available with the utility.

Table 3.9: Target Values of key Parameters Amarkantak Unit-1 and 2

Parameter	Target Value
Turbine Heat Rate (kCal/kWh)	2418
Auxiliary Power Consumption (%)	10
SOC (ml/kWh)	2

D. Performance Parameters

The period of R&M work of unit-1 was from 10.11.2010 to 24.03.2012 (16 Months) and Unit was synchronized on 19/02/2012. R&M of unit-2 was carried from 29.07.2009 to 11.09.2010 (13 Months) and Unit was synchronized on 26/08/2010. The key performance parameters for both the units have been shown in following table along with the values of environmental parameters. However, the values of unit outages before R&M were not made available.

Table 3.10: Amarkantak Unit-1 and 2 Performance Pre and Post R&M

Parameters	Pre R&M					Post R&M			
	Unit	2006-07	2007-08	2008-09	2009-10	2011-12	2012-13	2013-14	2014-15
Gross Generation (MU)	1	542.23	544.29	498.44	473.98	41.55	602.01	616.33	434.25
	2	566.60	424.70	515.60	145.07	384.86	657.43	648.86	58.92
PLF (%)	Common for both the units	52.74	45.96	48.23	29.45	20.22	59.91	60.18	23.46
APC (%)		11.71	11.82	12.53	13.48	10.62	9.46	9.82	11.83
SOC (ml/kWh)		2.88	3.08	4.07	7.49	6.76	3.37	2.23	1.92
SCC (kg/kWh)		0.82	0.81	0.81	0.77	0.78	0.8	0.8	0.76
Heat Rate (kCal/kWh)		3722	3750	3691	3520	3669	3765	3707	3431
GCV (kCal/kg)		4528	4572	4492	4578	4571	4671	4584	4526
Coal Consumption (MT)		Data not available				333560.422	1006111.07	1016796.71	372808.14
Planned Outage (hrs)	1					7799.3	0	734.33	0
	2					1775	0	580.03	0
Forced Outage (hrs)	1					452.58	1367.5	868.44	3201.2
	2					830.11	731.17	527.19	8108.1

Table 3.11: Amarkantak Unit-1 Environmental Parameters

Parameters	Pre R&M			Post R&M		
	2007-08	2008-09	2009-10	2012-13	2013-14	2014-15
SPM (mg/Nm^3)	148	188.33	147.83	133.75	125.81	125.7
SO_x (mg/m^3)	363.33	443.33	452.33	379.66	287.36	318.6
NO_x (mg/m^3)	251.75	349.16	336.83	245.83	214.81	237.8

Table 3.12: Amarkantak Unit-2 Environmental Parameters

Parameters	Pre R&M			Post R&M		
	2006-07	2007-08	2008-09	2010-11	2011-12	2012-13
SPM (mg/Nm^3)	147.66	146.81	198.91	Nil	132.28	131.75
SO_x (mg/m^3)	137.41	354.36	468.33	Nil	432	373.16
NO_x (mg/m^3)	81.33	239.09	398.33	Nil	243.85	244.83

E. Experience in O&M after R&M

Renovation & Modernization of both the units was carried out in phased manner during the year 2005 to March-2012. After R&M, performance of both the units improved at different fronts. The load in both the units was increased up to 90MW. The duration of R&M of both the units extended beyond the scheduled period due to unforeseen problems noticed after dismantling and inspection of the TG sets.

The gross generation, PLF, APC, SOC, SPM level, SO_x and NO_x level of both the units improved after R&M. SCC and Heat Rate remained more or less same after R&M compared to Pre R&M data.

The metal temperature of turbine bearing number 3 found to be 90 to 95 °C after conversion of water gland sealing system into steam gland sealing system. The main reason for this was due to steam leakage from gland box of IP turbine front end. Even after replacement of packing rings of IP front gland box during AOH work, this problem could not be rectified. However, as per the utility, this temperature increased gradually with the running of units and ultimately lead to load restriction and failure of bearing number 3.

The eccentricity of HP and IP turbine was running on higher side. Sometimes, it reached up to 250-300 microns particularly during rolling. However, during running of TG set, this value crossed the normal limits occasionally.

F. PG Test

Since R&M of both the units were carried out from 2005 to 2012 by various firms/contractors and comprehensive R&M by one firm was not carried out. Hence PG tests were not conducted on time as it was not in the scope of any firm. However, M/s. NASL handed over the units after successful completion of 14 days trial period for each unit with acceptable parameters at safe maximum load.

G. Problem/Challenges faced in O&M

The metal temperature of turbine bearing number 3 found to be 90 to 95 °C after conversion of water gland sealing system into steam gland sealing system. The main reason for this is due to steam leakage from gland box of IP turbine front end. Even after replacement of packing rings of IP front gland box during AOH work, this problem could not be rectified. M/s NASL has also stated that due to old unit with repaired rotors and casing, the bearing temperature of 95°C is normal for continuous operation. However, as per the utility, this temperature increased gradually with the running of units and ultimately lead to load restriction and failure of bearing number 3.

The eccentricity of HP and IP turbine was running on higher side. Sometimes, particularly during rolling reached up to 250-300 microns. M/s NASL clarified that rolling this value was acceptable as machine/rotors were very old and repaired. However, during running of TG set, this value crossed the normal limits occasionally. Since, the TG set has already completed more than 37 years against their expected life of 25 years and as per M/s NASL the IP casing of TG set has undergone major loss of material properties and plastic deformation in casing has taken place in TG set number 1.

H. Technical Surprises

Following technical surprises encountered during R&M of both the units.

Unit 1:

- Diaphragms were repaired
- Additional work of thermal straightening of the rotors and re-blading work of HP, IP and LP rotors
- Crack was found in IP casing which was rectified
- Additional work on generator rotor

Unit 2:

- Additional work of thermal straightening of the rotors and re-blading work of LP rotors
- Additional work on generator rotor

I. Reasons for Unsatisfactory Performance after R&M

- Due to power crises in the state during that period, the R&M work was carried out on need based and only very essential parts were replaced and work carried out. Comprehensive R&M was not carried out which might have yielded better results.
- The R&M period was very long and was carried out in phased manner. Initially R&M of Electrical, C&I and Boiler was carried out but the desired results could not be achieved because when R&M of turbine completed the effect of R&M of other equipment got diminished due to delay.

J. Overall Comments

After completion of R&M work the plant load factor was higher for the years 2012-13 and 2013-14. The PLF in the said years was 59.91% and 60.18% respectively, which was highest ever in last 11 years of operation.

3.3 Unit# 9 & 10 (2x200 MW) Obra Thermal Power Station, UPRUVNL, Uttar Pradesh

A. Background of the Project

The Obra Thermal Power Station is owned and operated by Uttar Pradesh Rajya Vidyut Utpadan Nigam Ltd. It is comprised of 5x50MW units (unit#1 to 5), 3x100MW units (unit#6 to 8) and 5x200MW (unit#9 to 13). The total generation capacity is 1288MW, of which unit numbers 3, 4, 5 & 6 have been declared obsolete and the capacity of unit numbers 7 & 8 have been de-rated to 94MW from 100MW.

It is located in Sonbhadra District of Uttar Pradesh. Obra TPS unit number 9 and 10 (2x200MW) were selected for renovation & modernization works. The last unit of 200MW plant was commissioned in 1982, both the units had completed their useful life of 25 years and were not operating at rated capacity and their PLF was also low with less efficiency.

The order for R&M was given for five unit i.e. units- 9, 10, 11, 12 & 13 to BHEL. This study undertakes unit 9 and 10 only for the review of experience. The contract was awarded to BHEL for carrying out comprehensive Residual Life Assessment (RLA) study of boilers of 2x200MW units. NTPC Ltd. was appointed as consultant for this project. RLA study of boiler of unit 9 was conducted by BHEL during 06.03.2007 to 13.03.2007 and that of unit 10 was done from 23.08.2006 to 04.09.2006. Final report of RLA/LE study was submitted by BHEL for unit 9 in March 2009 and that of unit 10 was submitted in August 2006.

BHEL team visited Obra TPS and collected details on the present condition of the boilers. Subsequently, a meeting was held between BHEL and UPRVUNL officials wherein the detailed scope of R&M was discussed and finalized. Most of the equipment/parts/components were considered for replacement for unit-10 and partial replacement for unit-9.

The scope of work included engineering, manufacturing/procurement, supply of equipment (both imported as well as indigenous), painting, testing, performance guarantee and commissioning of plant as envisaged and handing over of units as per agreed Programme viz. Boiler, Turbine, C&I, Generator & Exciter, Balance of Plants such as Coal Handling Plant, Ash Handling Plant, Water Treatment Plant, CW pump house, Switchgears, HT/LT motors etc. and ESP's (new replacement) in respect of refurbishment, overhauling, renovation, modernization and uprating of units.

B. Brief Scope of R&M Works for Unit-9 & 10

a. General

i) Refractory and thermal insulation:

Boiler furnace insulation, roof ceiling insulation, deck support, boiler second pass, hot air and flue gas ducts were found severely damaged. Replacement of complete refractory and insulation, GI sheets with fixing components for outer casing were replaced.

ii) Valves and fittings:

Replacement of HP & LP valves, root valves, feed control valves in both high capacity and low capacity lines, drum safety valves, RH safety valves, spray control valves for de-Superheaters in Superheater and Reheater, valves of PRDS system etc.

iii) Main steam pipe:

Straight piping of 20m length in MS, CRH & HRH piping were replaced.

b. Boiler Pressure Parts

i) Furnace Wall:

Drum level control problem, soot deposit over the tubes and silica & other deposits inside the tubes caused overheating and subsequent failure of tubes. 100% replacement of water wall along with water wall inlet and outlet headers is done.

ii) Boiler drum internals:

Overhauling/repair/replacement of damaged parts of boiler drum internals was done.

iii) Economizer:

100% replacement of economizer assemblies along with inlet and outlet headers with supports was considered.

iv) Super heaters:

Complete replacement of Platen super heater, Final super heater, Low temperature super heater, Ceiling super heater and Wall super heater was done along with super heater headers.

v) Reheater:

100% replacement of Reheater assemblies with headers and supports was done because of frequent failure of Reheater tubes. The material of Reheater tube was upgraded from T11 to T22 and T22 to T91.

c. Air and Flue gas system

i) Air heaters:

Air heater sector plate modification done for PA opening from 52° to 70°. 100% replacement of baskets, seals, sector plates and gear box was done.

ii) ID & FD fans:

Replacement of shaft assembly, impeller assembly, flange bearing with bearing housing assembly, external bearing and bearing housing assembly, shaft seals, expansion joints, IGV assembly and coupling was done.

iii) ID fans:

Erosion rate of ID fan components was higher due to poor ESP performance and severe air ingress into the ducting. Installation of suction box, impeller housing, OGV, Diffuser with access doors, Drain plugs, Lifting hooks, Fan impeller with shaft and bearings, IGV control was done.

iv) PA fans:

After sector modification of AH it was found that there was no problem for getting PA header and the existing PA fan capacity was sufficient for full load generation. This led to consider overhauling of PA system along with replacement of shaft assembly, impeller assembly, flange bearing with bearing housing assembly, external bearing and bearing housing assembly, shaft seals, expansion joints, IGV assembly and coupling.

v) Flue gas ducting:

100% replacement of flue gas ducting along with supports & insulation was done.

vi) Dampers:

All the dampers in cold and hot air ducts and in flue gas duct were replaced along with actuators. The hot PA shutoff gate and gate in mill tempering air duct were also replaced along with actuators.

d. Milling system

i) Raw coal feeders:

Replacement of six numbers existing raw coal feeders with dual belt Gravimetric feeder was done. The new feeders would be provided with state-of-art Eddy current clutch drive to have smooth, uniform and controlled feeder output.

ii) Wind box:

100% replacement of wind box was done.

iii) Coal burner:

Replacement of complete set of coal nozzle, coal nozzle tips, oil nozzle tips and air nozzle tips were done.

e. TG and auxiliaries:

100% replacement of HP turbine module. Replacement of rotor of IP and LP turbines was done.

f. Balance of Plant:

Installation of new compressed air system and air conditioning system was done.

C. Design Values of key Performance Parameters

Based on RLA/LE study recommendations, discussions and negotiations R&M and LE activities of unit-9 were finalized and has been shown in below table.

Table 3.13: Target Values of key Parameters of unit-9 of Obra TPS

S. No.	Parameter	Design Value	Target Value
1	Output Power	200 MW	216 MW
2	Turbine Heat Rate	NA	2007.6 kCal/kWh
3	ESP emission	428 mg/Nm^3 for 28.5% Ash in coal	100mg/Nm^3 with 46% Ash in coal
4	Boiler efficiency	86.15%	86.65%
5	SCC	Coal GCV varied	0.67 kg/kWh
6	Auxiliary Power Consumption	9%	9%

The target parameters fixed for Unit 10 for different parameters were as follows.

Table 3.14: Target Values of key Parameters of unit-10 of Obra TPS

S. No.	Parameter	Design Value	Target Value
1	Turbine Heat Rate	NA	2040 kCal/kWh
2	ESP emission	428mg/Nm^3 for 28.5% Ash in coal	NA
3	Boiler efficiency	86.15%	86.65%
4	SCC	NA	0.67 kg/kWh
5	Auxiliary Power Consumption	9%	Less than 9%

D. Performance Parameters

Performance parameters have been shown in below tables for both the units.
The R&M was done from 02nd November, 2008 to 26th June, 2011. Unit-9 was synchronized on 26th June, 2011.

Table 3.15: Obra Unit-9 Performance Pre and Post R&M.

Parameters	Pre R&M			Post R&M			
	2005-06	2006-07	2007-08	2011-12	2012-13	2013-14	2014-15
Gross Generation (MU)	936.12	865.33	873.88	928.07	1408.37	1165.70	1557.80
P.L.F (%)	53.43	49.39	49.74	52.83	88.39	79.36	88.92
APC (%)	11.84	11.75	12.27	9.81	9.47	9.30	9.98
SOC (ml/kWh)	3.13	4.20	3.75	1.30	1.42	1.61	3.15
SCC (kg/kWh)	0.86	0.91	0.92	0.85	0.78	0.80	0.92

Heat Rate (kCal/kWh)	3022	3371	3123	2731	2609	2520	2661
PAF (%)	82.23	77.36	76.40	63.23	90.45	89.35	94.30

Table 3.16: Obra Unit#9 Environmental Parameters and Forced Outages

S. No.	Environment Parameters	Pre R&M			Post R&M			
		2005-06	2006-07	2007-08	2012-13	2013-14	2014-15	2015-16
i.	SPM Level (mg/Nm^3)	800	800	800	199	160	156	137
ii.	Forced Outages (hrs.)	NA		2072.41	510.29	211.22	498.22	288.14
iii.	SO_x (mg/m^3)	The instruments used for measurement of these parameters have not been installed yet and are under proposal.						
iv.	NO_x (mg/m^3)							

R&M work of unit-10 was started on dated 22nd March 2012 and the unit was synchronized on 31st march 2016. The unit was shut down in July 2016 for major boiler works and again synchronized on 01st December, 2016.

Table 3.17: Obra Unit#10 Performance Pre and Post R&M

Parameters	Pre R&M			Post R&M
	2009-10	2010-11	2011-12	2016-17
Gross Generation (MU)	964.05	921.66	731.07	308.19
P.L.F (%)	55.03	52.61	41.61	41.92
APC (%)	12.48	13.00	11.84	11.48
SOC (ml/kWh)	3.08	4.30	1.30	9.33
SCC (kg/kWh)	0.94	0.88	0.85	0.85
Heat Rate (kCal/kWh)	3168	2803	2700	2586

Table 3.18: Obra Unit#10 Environmental Parameters and Outages

S. No.	Environment Parameters	Pre R&M		
		2007-08	2008-09	2009-10
i.	SPM Level (mg/Nm^3)	800	800	800
ii.	Forced Outage (Hrs)	1237.53	898.4	904
iii.	SO_x (mg/m^3)	NA	NA	NA
iiv.	NO_x (mg/m^3)	NA	NA	NA

The environment and outage data after R&M of the unit was not recorded by the utility.

E. Experience in O&M after R&M

Unit 9

i. The average PLF of unit increased to approximately 95% except rainy seasons.
ii. Boiler leakages have been minimal.
iii. Number of trippings of the unit have reduced.
iv. Specific Oil (SOC) and Specific Coal Consumption (SCC) have reduced thereby reducing cost of generation.

Unit 10

i. Unit runs at nearly 40% PLF

F. Problems /Challenges faced in O&M

Unit 9

i. Unit 9 runs at high axial shift up to (-) 0.98 mm at 200MW load. Problem not yet rectified since shut down of the unit has not been given to BHEL
ii. 15 numbers Auto Loops are out of service since their installation. These will be attended during overhauling of the unit.
iii. Secondary Air Damper Control (SADC) and Burner tilt have not been commissioned yet. The system does not work in Auto mode.
iv. HP heaters were charged in December 2013 before that there was high axial shift. The problem has not been resolved yet.
v. Fire and Smoke detection system not installed as it was not covered under R&M. This system will be planned for installation in due course.

Unit 10

i. Erection of Soot Blowers completed and half of them are working normal, for the other half the terminal block commissioning is under progress.
ii. 100% insulation ducting of ID, FD and PA fans not done causing loss of heat. Now the insulation on the ducting is complete.
iii. ESP field test at 45kV secondary voltage has not been done. The test was conducted successfully.
iv. Level indicators installed in HP and LP Heaters are not showing readings.
v. Generator Excitation System is faulty due to rusted components causing nuisance tripping of the unit. Now the fault is rectified.
vi. The vacuum created to carry out ash evacuation system is not sufficient causing choking of pipes. Also the gaskets provided at joints in the pipes are leaking causing drop in vacuum. Now the fault is rectified.
vii. The works of Control and Instrumentation system are still incomplete and interlocking and protection system appears to be unreliable.
viii. Human Machine Interface (HMI) installed are not sufficient in numbers. Old version of DCS system i.e. MaxDNA system of BHEL make has been installed which does not serve the purpose. Commissioning of this system is under progress.
ix. SO_x analyzer is still not commissioned. Vendor is awaited.
x. SWAS system is not fully functional. Vendor is awaited.

G. PG Test

Unit 9

Performance Guarantee test is not conducted because TG Auto loops, SADC, Burner Tilt, Colling Tower Fans have not been commissioned till date. Also there is axial shift problem in

Turbine and lastly the tapping points for measurement of different parameters were not provided at the time of R&M.

Unit 10

Performance Guarantee test is not conducted because TG Auto loops, SADC, Burner Tilt, Colling Tower Fans and a lot of Boiler side and turbine side instruments, and Ash handling work etc. have not been commissioned till date.

H. Main Reasons for satisfactory/unsatisfactory Performance after R&M

Unit 9

Performance of turbine is unsatisfactory due to increased maintenance.

Unit 10

BHEL were not ready to finish the R&M project even after completion of 8 years. Also many materials are yet to be delivered at site by BHEL.

I. Overall Comments

The performance of unit-9 has increased significantly in almost all fields viz. gross generation, PLF and Plant availability factor (PAF) have increased significantly while Forced outages, SPM, SOC and Heat Rate have decreased. Despite decrease in value of Heat Rate it has failed to achieve the target value. Similarly, SPM and APC have also failed to achieve its target value.

3.4 Unit 3 & 4 (2x110 MW) GNDTP, PSPCL, Bathinda, Punjab

A. Background of the Project

The Guru Nanak Dev Thermal Power (GNDTP) at Bathinda has a total installed capacity of 440MW (4x110MW) in two stages. Stage I consists of two units of 110MW each i.e. Unit# 1&2 and Stage II comprises two units of 110MW each i.e. Unit# 3&4. Unit#3 was first commissioned on 29th March 1978 and Unit# 4 was first commissioned back in 31st January 1979 thereby completed more than 20 years of service at the time of RLA study and were facing problems of ageing of critical components, non-availability of spares, obsolescence of technology and reduced performance parameters. To overcome these problems, GNDTP had proposed to carry out Residual Life Assessment study coupled with a study of Renovation, Modernization and Life Extension to achieve the overall objectives of improvement in

- Plant Load Factor
- Plant Availability
- Plant load to achieve rated capacity
- Efficiency improvement in Boiler, Turbine, Generator and auxiliaries
- Reduction in emission and improvement in operating environment around the plant

Bathinda TPS unit-3 and 4 were undertaken for R&M and LE Programme. The contract was awarded to Central Power Research Institute, Bangalore for carrying out comprehensive Residual Life Assessment (RLA) study of boilers of 2x110MW units. RLA study of unit-3 was conducted in the year 2000 and that of unit-4 was done in 2001.

B. Brief Scope of R&M Works

The major Scope of R&M works under various packages were as follows.

a) Boiler:

Complete replacement of existing indirect fired Boiler with direct fired BHEL make Boiler having membrane type water walls, Drum internals. Replacement of air heaters,

flue gas ducting, fuel firing system. Up-gradation of milling system for direct firing, replacement of old drums type mills with bowl type vertical mills. Replacement of old ID/FD/PA Fans along with motors.

b) Turbine:

Replacement of HP, IP & LP rotors along with HP inner, IP inner & LP casing, Turbine gland sealing system, Turbine Lube Oil Coolers, impellers of CW pumps with stainless steel impellers, HP Heaters, tube nest of various LP Heaters, Condensate Extraction pumps with motors, control valves, Butterfly valves & RCVs.

c) Balance of Plant:

Replacement of old outdated ESP controllers with micro-processor based controllers & HVRs along with internals & rapping system. Addition of two fields in each pass of ESP. Replacement of existing ash slurry lines with new ones, ash slurry pumps, seal water pumps & strainers in HP water line. Providing of additional clinker grinders.

d) Electrical:

Replacement of 220 kV Air Blast Circuit Breakers with SF6 Circuit Breakers, protection relays, Generator Field Breakers, pneumatic operating mechanism of 220 kV Isolators with motor operating mechanism & HT/LT cables. Retrofitting of 6.6 kV MOCBs with Vacuum Circuit Breakers.

e) Control & Instrumentation:

Replacement of Old Russian type C&I system with state of the art functionally distributed microprocessor based digital distributed control system. Providing of Furnace Safeguard Supervisory System (FSSS), Secondary Air Damper Control System (SADC), Soot Blower Control System (SBCS), Automatic Turbine Run up System (ATRS), Electro-hydraulic Governing System & Turbine Protection System.

C. Design Values of key Performance Parameters

Based on RLA/LE study recommendations, discussions and negotiations, R&M and LE activities were finalized for achieving up-rated capacity generation of 120MW at TG gross output at 3% make-up and 0.1208 kg/cm^2 of condenser vacuum.

Table 3.19: Design Parameters of GNDTP Unit-3 & 4

S. No.	Parameter	Target Values
1	Target Power Output	120 MW
2	Turbine Heat Rate	1990 kCal/kWh
3	Auxiliary Power Consumption	8.5 %
4	Boiler Efficiency	87.5 %
5	SPM	90 mg/Nm^3

D. Performance Parameters

Unit-3

R&M works carried out from 14.01.2010 to 18.07.2012 and unit was synchronized on 05.08.2012 and stabilized on 07.12.2012. Period of R&M work: 14.01.2010 to 06.12.2012

(1057 Days). The unit was shut down since 22.12.2006 and it was synchronized on 18.07.2012.

Table 3.20: GNDTP Unit-3 Performance Pre and Post R&M

Parameters	Pre R&M			Post R&M		
	2007-08	2008-09	2009-10	2013-14	2014-15	2015-16
Gross Generation (MU)	693.8	661.45	537.193	463.118	570.108	314.404
Peak Load (MW)	97	98	95	125	127	124
PLF (%)	71.8	68.64	55.75	44.06	54.23	29.83
APC Stage-2 (%)	11.4	12.36	12.75	10.88	10.71	10.72
SOC (ml/kWh)	1.77	3.22	3.68	2.04	1.44	1.86
SCC (kg/kWh)	0.734	0.74	0.794	0.617	0.64	0.691
Heat Rate (kCal/kWh)	3084.21	3168.79	3267.52	2577.64	2658.25	2825.74
Cost of Generation Station (Paisa/kWh)	205.45	227.49	243.67	413.58	479	595.19
Coal Consumption (MT)	509519	489474	426421	285274	365090	217372

Table 3.21: GNDTP Unit-3 Environmental Parameters and Outages

S. No.	Environment Parameters	Pre R&M				Post R&M		
		2006-07	2007-08	2008-09	2009-10	2013-14	2014-15	2015-16
1	SPM (mg/Nm^3)	141.37	145.56	138.98	NA	84.90	108.20	87.82
2	SO_x (mg/m^3)	257.33	267.61	267.77	NA	381.65	403.47	324.73
3	NO_x (mg/m^3)	1.46	1.56	1.63	NA	2.18	2.09	1.79
4	Forced Outage (%)	NA	5.76	4.78	6.19	28.15	2.27	6.08
5	Planned Outage (%)	NA	6.41	6.27	21.10	0.00	4.38	4.09

Unit-4

R&M works carried out from 05.11.2011 to 26.09.2014 and unit was synchronized on 10.07.2014 on coal and stabilized on 27.09.2014. The unit was shut down since 22.12.2006 and it was synchronized on 23.06.2014.

Table 3.22: GNDTP Unit-4 Performance Pre and Post R&M

Parameters	Pre R&M			Post R&M
	2008-09	**2009-10**	**2010-11**	**2015-16**
Gross Generation (MU)	622.58	611.227	428.675	199.281
Peak Load (MW)	98	92	87	124
PLF (%)	64.61	63.43	44.49	18.91
APC Stage-2 (%)	12.36	12.75	14.87	10.72
SOC (ml/kWh)	4.74	5.37	10.18	3.42
SCC (kg/kWh)	0.747	0.801	0.823	0.696
Heat Rate (kCal/kWh)	3214.16	3313.63	3335.36	2858.69
Cost of Generation Station (Paisa/kWh)	227.49	243.67	307.53	595.19
Coal Consumption (MT)	465168	489741	352919	138679

Table 3.23: GNDTP Unit 4 Environmental Parameters and Outages

S. No.	Environment Parameters	Pre R&M			Post R&M
		2008-09	**2009-10**	**2010-11**	**2015-16**
1	SPM (mg/Nm^3)	145.84	144.14	143.90	117.01
2	SO_x (mg/m^3)	268.98	241.29	271.02	361.67
3	NO_x (mg/m^3)	1.55	1.53	1.44	1.85
4	Forced Outage (%)	5.80	4.62	25.31	0.90
5	Planned Outage (%)	6.02	7.69	0.00	0.00

E. Experience in O&M after R&M:

Under R&M, firing system of units were changed to direct firing system based on bowl type mills in place of indirect firing system based on ball mills. There has been complete replacement of instrumentation. BHEL make max DNA DCS has been installed which provides HMI based control monitoring & operation of units from the control room. These major changes along with shortage of operating staff faced many challenges in the beginning. However, with passage of time staff got acquainted with the changes and now the operation is very smooth. Quality of equipment supplied by BHEL is very good and there are no major maintenance problems. However, quality of execution of work at site was not up to the desired mark which caused some maintenance problems which have been detailed in Table 3.24 along with remedial measures taken to resolve them. The units achieved the peak load of more than 120MW after capacity uprating from 10MW to 120MW. The performance of both the units improved in some aspect like APC, SOC, SCC, Heat Rate etc. after R&M. Post R&M Experience in operation performance of the Unit were as follows.

i. Increased availability & Generation updated to 120 MW
ii. Improved efficiency
iii. Excellent ESP

F. Problems/Challenges faced in O&M after Implementation of R&M

After the units run for a reasonable period, post implementation of R&M works, following problems/challenges were faced in O&M as detailed in below table.

Table 3.24: Problems/Challenges faced at GNDTP

S. No.	Area	Problems / Challenges faced after implementation of R&M interventions	Remedial Measures Taken / Suggested
i.	**Boiler**		
	Coal Mills	With design PA flow, coal mill reject increased	Because of space limitation Primary air ducts to coal mills could not be laid in accordance to system requirement. There were sharp cuts in PA ducts to coal mills. To get the desired output from mill PA flow had to be kept more than the design limit. To overcome this problem, Air port assemblies' gap was reduced from 95-100 mm to 55-60 mm air consultation with experts of M/s BHEL. With this modification mill rejects problem got solved and now Primary air flow to coal ratio is just 1.7 which is well within the design limits.
	Others	Frequent joint leakages from economizer banks.	100% radiography of economizer's joints was done and defective joints re-welded. It is suggested that during erection of the Boiler 100 % radiography of joints at site be done instead of present practice of only 10%.
		Mal-functioning of pressure reducing valve	To overcome this problem temporarily suitable rating globe valves which were available at site were installed upstream of these valves on both the units-3 & 4 to regulate the pressure. After thoroughly examining the problem, spring tension of actuators of these valves were adjusted and one of the valves gave positive results.
ii.	**Ash Handling System**	Slow evacuation of ash from ESP hoppers resulting in filling of hoppers up to emitting plates	The evacuation of ash from ESP hoppers was done by vacuum system on dry mode. Fluidizing air was used to be provided intermittently design resulting in poor flow of ash, the same was modified to continuous design. The problem is solved to a large extent but in case of poor quality of coal, first two fields give problem in evacuation. M/s BHEL were contacted and they suggested installation of pressurized conveying system for these two fields. The work of installation of this system on Unit 3 & 4 is in progress.

iii.	**C&I Systems**		
		Tripping of DCS Panels on UV/OV in case of input supply source changeover for 24V DC Charger.	Laying additional cables to Battery Bank for reducing voltage drop & bypassing dropping diode. Tripping of panel still occurs during grid disturbance condition but additional monitoring signals and control signals have been wired to ensure quick detection and safety of critical equipment.
		Higher Failure Rate of DCS Cards	The supply scheme to the problematic field equipment (Solenoid valves in this case) was thoroughly checked and it was observed that 24V Grounded supply was used to drive the solenoid which was putting a jerk on Cards/DPU Power Supplies. Solenoids were then given required ungrounded isolated supply. With the change in solenoid supply scheme, there was drastic fall in card failure rate.
		Disturbances in Analog Input Signals	The shield and power ground was found mixed in the panels. The same were corrected. Signal stability is observed to be normal now.
		Frequent Flame Failure Trippings on Unit #3 even on full load.	After thorough check it was observed that Scanner lengths was not up to the furnace end. The lengths have been corrected by inserting nipples to achieve the correct distance from furnace end.
		Delay in tripping of turbine on lube oil pressure low.	It was observed that due to insufficient header diameter there was time loss in transmission of lube oil pressure changes to the pressure switches which were to be activated from the header. Header size was changed and now the time lag has been corrected.
iv.	**Electrical**		
		There was frequent tripping of Gravimetric feeders installed on Units 3 &4 of the units.	The make of VFDs was changed. The problem has been solved.
		415V LT breakers have outlived their life and spares are not available. There is frequent problem in maintenance of these breakers.	The LT breakers are being replaced in the phased manner.
		Problem of 24V DC battery chargers. The DPUs of DCS trips on under voltage.	Problem minimized but yet to be rectified completely.
		Two Mac Cards of Vacuum Contactors of 6.6	Cards were replaced.

		kV coal mill motors were damaged.	
		Distance protection relays of transmission lines, Bus bar protection scheme and various protections of transformers were old electromagnetic type or obsolete type. CPRI in its protection audit recommended to replace these relays	Action is initiated to replace these old/ obsolete protection relays with latest numeric protection relays.
		Problem of power evacuation with existing GTs & UATs due to enhancement of unit capacity from 110MW to 120 MW for unit 3 & 4.	GTs & UATs of enhanced capacity were installed post R&M.

G. PG Test

PG tests of unit 3 and 4 have been done. Guaranteed values of Gross Output Power was achieved during PG tests. Results of Boiler efficiency and APC of both the units have achieved targeted values. Results of PG test of Turbine Heat Rate of both the units-3&4 were achieved. Actual Turbine Heat Rate as per PG test of unit-3 was 1989.23 kCal/kWh and actual Turbine Heat Rate as per PG test of unit-4 was 1979 kCal/kWh against the targeted Heat Rate value of 1990 kCal/kWh for both the units. Average values of SPM level was from 32.7 to <100 mg/Nm^3 for unit-3 and it was from 24.2 to <100 mg/Nm^3 for unit-4 during PG tests. Average values of SO_2 level was from 315 to <550 mg/Nm^3 for unit-3 and it was from 56 to <450 mg/Nm^3 for unit-4 during PG tests. Average values of NO_x level was from 197 to <550 mg/Nm^3 for unit-3 and it was from 35 to <450 mg/Nm^3 for unit-4 during PG tests.

H. Reasons for Satisfactory/Unsatisfactory Performance after R&M

Performance of the units have been satisfactory. Availability of the units has increased considerably. Moreover, there has been capacity addition of 10 MW. Replacement of Turbine rotors & Boiler has helped in attaining operational efficiencies which are at par with units of higher capacities of 210/250 MW.

I. Benefits Accrued

Benefits of R&M are enlisted below:

a) Better availability and efficiency in terms of Heat Rate
b) Lower auxiliary power consumption in both units
c) Ease of operation
d) Better safety with introduction of Furnace Safeguard Supervisory System
e) Better compliance of environmental pollution norms
f) Enhanced guaranteed capacity of both units
g) extension in useful life up to 20 years

3.5 Unit 1 (1x110 MW) Muzaffarpur TPS, KBUNL (BIHAR)

A. Brief History of the Project:

Kanti Bijlee Utpadan Nigam Limited (KBUNL) Thermal power Station, Muzaffarpur (MTPS) is a subsidiary of NTPC Ltd. consisting of 2x110 MW Units, was established by BSEB. The first 110 MW Unit was commissioned on 31.03.1985 and the second unit was commissioned on 17.03.1986. Total running hour of unit#1 is 66202 hours and that of unit #2 is 69383.58 hours. Unit #1 was under shut downed on 14:25 Hrs. of 06.10.2003 and unit#2 under shut downed on 09.52 Hrs. of 03.10.2003. On the proposal of Govt. of Bihar for Renovation & Modernization/Life Extension of (2x110 MW Units) Muzaffarpur TPS & (2x110MW Units) Barauni TPS, a Memorandum of Understanding was signed amongst MoP (Govt. of India) ,Govt. of Bihar, NTPC, BHEL & BSEB on 29.05.2006. As per MOU it was envisaged that the R&M of BTG & BOP of MTPS would be carried out at the cost not exceeding Rs1.25 Crores/MW. Planning Commission vide their letter dated 16.11.2009 approved the revised cost estimates of Rs. 1053 crores including consultancy charges under the Special Plan for Bihar for LE works of Barauni TPS (Unit 6&7) and Muzaffarpur TPS (Unit 1&2). The cost of R&M of Muzaffarpur TPS was estimed to be Rs. 471.80/- Crores.

Ministry of Power/Planning Commission recommended BHEL as implementing agency for the RLA & R&M/LE works and NTPC as Consultant. Final agreed scope and cost shall be vetted by CEA. A Memorandum of Agreement (MOA) was signed among Government of Bihar and Bihar State Electricity Board (BSEB) and NTPC Limited on 26.12.2005 with an intent to promote a Joint Venture Company namely Vaishali Power Generating Company Ltd. (VPGCL). The objective of JVC was to Acquire, Establish, Operate & Maintain and take up the Expansion Project (500 MW) of the Muzaffarpur Thermal Power Station. NTPC & BSEB have equity participation of 51% and 49% respectively. VPGCL has been incorporated with the Registrar of Companies, Delhi & Haryana on 06.09.2006. Subsequently, the name of the company has been changed to Kanti Bijlee Utpadan Nigam Limited (KBUNL) on 10.04.08. KBUNL has appointed NTPC Limited as Consultant to implement R&M program for MTPS 2x110MW Units.

B. Brief Scope of R&M Works

The major scope of R&M works under various packages are as follows:

1) Boiler

a) Pressure parts:

100% Replacement of Furnace water wall, Extended water wall, Radiant Roof (First pass) & roof tubes of second pass, Screen Tubes (WW & Super heater), Hanger Tubes (WW & Super heater), Platen Super heater coils , Economizer Coils, Reheater coils , 25% replacement of SCW, 50% replacement of LTSH & terminal tubes, SH/ RH/ DESH station, Drum internals & fasteners, Furnace bottom Seal plate, , Drains and Vents, Safety valves at Drum, RH, SH and ERV.

b) Draft System:

Impeller, shaft with bearing, expansion joints, Labyrinth seal assembly, IGV assembly, replaced for FD fan. Impeller, shaft with bearing, Labyrinth seal assembly, IGV assembly, lube oil pump, cooler & filter, lube oil system with integral valves replaced for PA Fan. Complete rotor assembly, Hydraulic coupling with connecting coupling & modified cooler, casing liner replaced for ID fans. Complete replacement with motor for seal air fans.

2) Turbine

a) Main Turbine:

Refurbishment of LP/ IP & HP turbines, new supply of all Flexible hoses, Refurbishment of Shaft Turning Gear, Turbine governing valves. Refurbishment of Turbine Gland Sealing System.

b) Heat Exchanger:

Replacement of HP heaters I & II along with Supply of complete drip and drain valves including piping along with actuators with electronic level control, Supply & replacement of Tube Bundles of LP heaters I-V, gland steam condenser, chimney steam condenser, Refurbishment of Steam Jet Air Ejector with replacing nozzles, diffusers & Tubes.

3) Generator

Refurbishing of gas manifold valves of Generators including Liquid Level Detector, Supply of AC & DC seal oil pumps, Vacuum Pumps (skid mounted pumps along with their motors), DPRs, seal oil coolers for air and hydrogen side along with control panel, Supply of new shaft seals. Refurbishment of generator bus-duct, air pressurization system and NGT.

4) Balance of Plant

Supply of skid mounted HP/LP dosing system, Supply & replacement of inlet/outlet isolating butterfly valves & rubber expansion. R&M of pre-treatment plant, bore well mechanical system, firefighting system, DM plant, chlorination plant, cooling tower, compressed air system, air conditioning system and ash handling system, fuel oil system, workshop, CW system, raw water system, wagon tipplers, vibro-feeder, rail track & miscellaneous works, procurement of shunting locomotive, R&M of ash dyke, township and main plant civil.

5) Electrical

CHP electrical system, 220/132 kV switchyard & transformers, plant illumination, R&M of ESP electrical system, LT& HT switchgear replacement, HT/LT motors, DAVR of one unit, HT/LT cables & miscellaneous, transformers & plant earthing system. Refurbishment of GT, UAT, ST& IPBD. Replacement of GRP1 & GRP2 with microprocessor based numerical type dual protection relay panels including generator transformer & UAT Protection, Implementation of auto bus changeover scheme. Refurbishment of 17 umbers Siemens make SF_6 breaker including supply of necessary spares & consumables for refurbishment.

6) Control & Instrumentation

Replacement of all field instrumentations, implementation of max DNA Digital Control System, SWAS and Flue gas analyzers. Replacement of control room relay based panel by card base. Replacement of push button type operating system to computer based, LVS, R&M of control system of CW, AHP & CHP. R&M of oil facility/ LDO/ HFO unloading systems.

C. Performance Parameters

i. Performance Parameters Pre R&M

Unit was Under Shut down since 06.10.2003 before starting R&M on 15.04.2010. No data is available for Pre R&M period as unit was under shut down since 06.10.2003. However, as enquired from Plant Authorities, unit was running at 10-15% PLF before undertaking R&M.

ii. Performance Parameters Post R&M

Performance Parameters (Post R&M) of 110 MW unit No. 1 of Muzaffarpur is as follows. Period of R&M Works: From 15.04.2010 to 05.07.2013.

Table 3.25: MTPS Unit-1 Performance Parameters Post R&M

Parameters	Post R&M		
	2013-14	**2014-15**	**2015-16**
Gross Generation (MU)	319.09	687.20	211.28
P.L.F (%)	80.05	71.32	37.40
APC (%)	11.63	11.32	15.40*
SOC (ml/kWh)	3.23	2.51	5.82
SCC (kg/kWh)	0.79	0.761	0.78
Heat Rate (kCal/kWh)	3087	3001.29	2978.82

** The APC recorded during 2015-16 was higher as the Generation was low and PLF also recorded low*

Table 3.26: MTPS Unit-1 Environmental Parameters

S. No.	Environment Parameters	Before R&M/LE	Target Value of R&M/LE	Actual after R&M/LE
i.	SPM Level (mg/Nm^3)	NA	Not covered under Contract	55/61
ii.	SO_x (ppm)	NA	--do--	246
iii.	NO_x (ppm)	NA	--do--	107

D. Problems/challenges faced in O&M after R&M

The problems/challenges faced were as follows.

i. The grinding elements supplied by BHEL are failing before their assigned life.
ii. Failure of 4/4a blades of LP turbine
iii. Failure of gaskets in Turbine
iv. Ash dumping & air monitoring since erection & commissioning of CO/SO_X/NO_X analyzer is not completed.

E. Status of PG Test

PG test have not been conducted yet since BHEL was to submit the revised Turbine PG test/demonstration which has not yet been submitted by them. However, Boiler PG test proposal has been finalized by both end i.e. between BHEL and NTPC Ltd.

3.6 Unit# 7 (1x110 MW) Barauni TPS, BSEB, BIHAR

A. Background of the Project:

Renovation and modernization of 110 MW Unit 7 of Barauni Thermal Power Station was initially expected to be completed in November 2011. However, delay in the main plant works of the units delayed the projects. According to the project authorities, the Units were expected to be completed by January/February-2016. The R&M of Barauni Units is being carried out by the Bihar State Electricity Board. The main plant package contractor for the project is BHEL. The unit was synchronized on oil only but its synchronization on coal is still awaited.

The Barauni TPS units 6 and 7 of 110 MW capacity each were commissioned during May 1983 and March 1985 respectively. Under RSVY now BRGF, Planning Commission in a meeting held on 10.05.2005 identified both Barauni TPS, units 6&7 and Muzaffarpur TPS units 1&2 for carrying out Life Extension (LE) works. Subsequently, a five party agreement between the Government of India, Govt. of Bihar, BSEB, BHEL and NTPC was signed on 29.5.2006. Planning Commission vide their letter dated 16.11.2009 approved the revised cost estimates of Rs. 1053 crores including consultancy charges under the Special Plan for Bihar for LE works of Barauni TPS (Unit-6&7) and Muzaffarpur TPS (Unit-1&2) as per details given below:

Barauni TPS Unit (6&7)	:	Rs. 554.16 crores
Muzaffarpur TPS (1&2)	:	Rs. 471.80 Crores
Consultancy charges to NTPC (For Barauni TPS only)	:	Rs. 27.04 Crores
TOTAL	**:**	**Rs. 1053.00 Crores**

Renovation and Modernization of 110 MW Unit no. 7 of Barauni Thermal Power Station was taken up for the study. The unit was under shutdown from 29th May, 2006 and its R&M was taken up in 2011.

Zero date of R&M of this unit was 15th November, 2009 and the Contractual Completion date was 15th November, 2011. The anticipated completion date was 31st July, 2016, however, the unit was synchronized on oil firing on 28th February, 2016 and the unit was synchronized on coal on 03rd August, 2016. However, delay in the main plant works of the units delayed the projects. The main plant package contractor for the project is BHEL. The target values of different parameters were as under.

Table 3.27: Target Values of Parameters of Unit-7 Barauni TPS

S. No.	Parameter	Target Value
1	Turbine Heat Rate (kCal/kg)	2172
2	Boiler Efficiency (%)	83.0

B. Performance Parameters

Performance Parameters (Pre R&M) of 110 MW unit No. 7 of Barauni TPS is as follows.

Table 3.28: Unit-7 Barauni TPS Performance Parameters Pre R&M

Parameters	Pre R&M			Post R&M
	2003-04	2004-05	2005-06	2016-17
Gross Generation (MU)	140.805	115.19	37.47	57.57
P.L.F (%)	15.26	12.49	3.89	17.15
APC (%)	16.37	20.04	20.77	12.00
SOC (ml/kWh)	18.61	16.27	19.05	29.64
SCC (kg/kWh)	1.07	1.09	1.10	0.79
Heat Rate (kCal/kWh)	5397.27	5616.95	5553.50	NA
DM Water Consumption(m^3)	153029	113784	99324	NA
Coal Consumption (Ton)	152056	126239	41577	45282
Peak Load (MW)	60	50	50	109.3

**Note: COD of the unit was declared on 04/11/2016. The unit run for two months i.e. November & December, 2016*

Table 3.29: Unit-7 Barauni TPS Environmental Parameters and Outages

Parameters	Pre R&M			Post R&M
	2003-04	2004-05	2005-06	2016-17
SPM (mg/Nm^3)	Instruments was not installed			Instruments are being installed
SO_x (mg/m^3)				
NO_x (mg/m^3)				
Forced Outages+ Planned Outages (Nos.)	48	47	18	NA

C. PG Test Status

Since, the unit is still under stabilization therefore, the Performance Guarantee (PG) tests could not be completed at this stage.

D. Problems and Challenges faced in O&M after R&M

a) Frequent tripping of unit no. 7 on different tripping logics i.e. drum level low and high etc. due to malfunction of various transmitters.

b) Sometimes DCS signal do not operate during operation due to which unit is tripping frequently.

c) In DCS system, some tripping command is activated from those transmitters, the value of which is not shown on screen during normal operation. For example, in ID fan, tripping of fan is actuated from Low Lube oil Pressure whereas in DCS Panel only Bearing oil temperature is being shown etc.

d) Sometimes current variations occurred in the coal feeder due to blockage of feeder inlet line. Trial run of mill D and E have not yet complete.

e) The performance of ID and FD fans were satisfactory but vibrations were observed in PA fans, which were resolved. Non-drive end side bearing of ID fan-B was damaged due to ingress of water, which was later replaced.
f) Turbine could not come immediately on Barring gear after tripping, as observed on 2-3 occasions, the cause of this is being investigated.
g) Lube oil leakage was observed in BFP, it was rectified.
h) Vibrations in newly installed CEP-C observed which was replaced by the older one.
i) Termination of cables of C&I instruments have not been done properly because of which sometimes the equipment fail to operate.
j) Hot air, Cold air gate and dampers of mill system do not operate properly because of heavy leakages in the instrument air-line.
k) Canopy over C&M instruments/machine are not present which is hampering smooth operation of these systems as rain/drain water fall over them.
l) Because of incomplete/improper insulation of turbine body, cables and RTD got damaged which were later replaced.
m) Wagon tippler was not working properly. When loaded wagon was being lifted, tripping of wagon tippler MCC occurred. Spark was observed from the panel and contactor got melted. The problem was rectified by laying down a cable parallel to the existing one for strengthening voltage and reducing voltage drop and by increasing contactor capacity to 300A from 250A.

E. Experience in O&M after R&M

Operation of unit by implementation of DCS has become more user friendly and all the operation parameters were being monitored properly. Lack of spares, air motor of APH not functioning smoothly, capacity of FD fan is low therefore, secondary air-primary air ratio is not maintained etc. are few problems being faced by the utility after R&M.

F. Reasons for satisfactory/unsatisfactory Performance

a) The RLA was done in the year 2009-10 whereas the work of R&M was started in 2011. It took about five years in completion of R&M work. During this period, the equipment/pipeline which were found healthy during RLA were further deteriorated and were creating problems.
b) Performance of the unit is being monitored as the unit is still under stabilization.

3.7 Unit#5 (210 MW) Bandel TPS, WBPDCL, West Bengal

A. Background of the Project

Bandel Thermal Power Station (BTPS) is owned and operated by West Bengal Power Development Corporation Ltd has an installed capacity of 740MW, comprising of five units (3x100+2x210MW). It is located in Tribeni, Hooghly District, about 120km north-east of Kolkata. Unit#5 was commissioned on 8th October 1982. It had clocked 141420 hours i.e. an overall availability of about 67% till the RLA study was done by NTPC-Alstom Power Services Private Limited (NASL) in December 2006. The tenders for R&M works were invited through International Competitive Bidding (ICB) during Dec., 2010. The total revised estimated project cost was Rs. 652.2/- Crores. The main package BTG was awarded to M/s DHIC (Doosan Heavy Industries & Construction) Korea and M/s DPSI (Doosan Power System India) on 29.02.2012 at a cost of Rs. 531/- Crores i.e.Rs.290.98/- crore+37.58 Million

Euros. The package for CHP was awarded to M/s Vinar System Pvt. Ltd. on 31.01.2013 at a cost of Rs. 26.63/- crores. The package for electrical works was awarded to M/s Alstom T&D India Ltd. on 28.12.2012 at a cost of Rs. 16.31/- crores.

B. Brief Scope of R&M Works

The major scope of R&M works under various packages are as follows.

i. Boiler & Auxiliaries:

a) Coal Mill:
Installations of new coal and oil burner system, New Mill (8.5E9) along with coal feeders.
b) Complete replacement of Platen SH, Primary SH (Horizontal Bank), Economizer, Front side water wall and S panel etc.
c) Complete replacement of Wind box, Damper, Expansion joint and ducts in flue gas as well as air path along with soot blowing system.
d) Air Preheater (APH):
Installation of one new APH bank as well as complete tube replacement of existing APH to maintain the outlet flue gas temperature at 135°C.

ii. Turbine & Auxiliaries:

a) Installation of Digital Electrohydraulic (DEH) governing system in place of Hydraulic governing system.
b) Replacement of BFP cartridge, installation of new CEPs, overhauling of Drip pump, CW and RCW pump.
c) LP Heaters: Complete tube replacement of LP Heaters with suitable HBD tubes as well as of condenser tubes.
d) Replacement of HP heater tubes, new De-Aerator, new Auxiliary PRDS, new Ejector, Gland Steam condenser and vent steam condenser and new HP-LP bypass system.
e) Repair/replacement of major valves.

iii. Generator:

Complete replacement of existing generator by a new 215MW Generator having 0.85pf lag, 3000 rpm, terminal voltage 15.75 kV, water cooled stator winding, Hydrogen cooled rotor as well as stator core with other relevant parameters of existing Generator with bearings including bearing pedestal. Replacement of existing Generator/Generator Transformer protection system by dual redundant Numeric Relay based protection system including necessary replacement of CT and PT of desired accuracy.

iv. Control and Instrumentation:

Complete replacement of existing relay logic and Analog controlled open and closed loop automation system by new set of distributed digital control and management information system (DDCMIS).

C. Target and Achieved Values of Key Parameters

The unit was tested at the load of 186MW for the achievement of target values on 09th May, 2016 for following parameters. Since the unit was running below its Maximum Continuous Rating (MCR), the parameters were almost near its achievement as can be seen for Heat Rate, Specific Coal Consumption and the biggest achievement was the SPM level which was well below its target values.

Table 3.30: Target Values of key Parameters of Unit-5 of Bandel TPS

S. No.	Parameter	Target Value	Value Achieved (During PG Test)
1	Gross Power Output (MW)	215	220
2	Gross Unit Heat Rate (kCal/kWh)	2345	2287
3	APC (%)	6.04	5.13
4	SPM (mg/Nm^3)	90	79.20

D. Performance Parameters

The performance parameters of unit-5 of Bandel TPS Pre and Post R&M have been shown in following table. During May 2016 Unit-5 was running on part load as only one HP control valve available. From 10th June, 2016 to 19th July, 2016 unit#5 was shut down for remaining left out jobs of Doosan.

Table 3.31: Unit-5 Bandel TPS Performance Parameters Pre and Post R&M

Parameters	Pre R&M			Post R&M
	2011-12	2012-13	2013-14	2016-17
Gross Generation (MU)	1066.98	916.73	596.32	776.11
Peak Load (MW)	NA	205	195	225
PLF (%)	57.82	49.83	32.41	54.66
APC for Unit 1 to 5 (%)	11.63	11.54	12.82	12.08
SOC (ml/kWh)	4.7	4.01	12.08	5.22
SCC (kg/kWh)	0.88	0.84	0.88	0.693
Heat Rate (kCal/kWh)	3297.96	3007	3173	2285
DM Water Consumption (m^3)	NA	59500	46229	36829
Coal Consumption (MT)	945060	70025	543756	454404.56
Forced Outages (%)	5.18	25.06	11.12	10.36
Planned Outages (%)	1	0	0	14.04

Table 3.32: Unit-5 Bandel TPS Environmental Parameters

Parameter	Pre R&M			Post R&M
	2011-12	2012-13	2013-14	2016-17
SPM (mg/Nm^3)	153	126	123	68.18
SO_x (mg/m^3)	758	624	478	488.26
NO_x (mg/m^3)	628	544	429	348.19

Post R&M, the efficiency of HP turbine was 76.5%, for IP turbine it was 95.1% and that of LP turbine was 70% calculated at the load of 186MW on 09 May-2016. From the comparison of Pre-R&M performance parameters with Post-R&M performance, so far, it was observed that there is no significant improvement in various parameters of the unit because stable operation has not been achieved so far, even though full load of 215MW was achieved for a short period only. Moreover, even Reliability operation has not been demonstrated by the Main Contractor i.e. M/s Doosan.

E. Experience in O&M after R&M

The experience shared by TPS in which R&M work was done is highlighted below.

- The unit achieved target load of 215MW. It also touched 225MW i.e. 10MW more than its target value.
- The Heat Rate value achieved tremendously good performance after R&M.
- The SCC value after R&M was also good.
- Operation through DCS become more user-friendly and all parameters are monitored properly.
- Various Auto control loops like drum level control, air flow control, temperature control, turbine follow mode, CMC are functioning satisfactorily.
- SOC and SCC etc. are improved with respect to pre R&M.

F. Problems and Challenges faced in O&M after R&M

Problems/challenges faced in O&M of thermal unit after implementation of the R&M interventions and Suitable measures for further improvements. Improvement, can be brought out only after completion of works and operation of unit far a reasonable period. Frequent failure of transmitter of HP control valve, frequent tripping of coal feeder due to specific design of clean out conveyor provided as per site condition, frequent tripping of mill dynamic classifier due to overload and Starting Air Ejector taking more time to achieve desired vacuum etc. were some of the problems faced in O&M after implementation of R&M. Some more details have been given in the following table.

There was alignment problem in PA fan bearings which were then sent to OEM. There was design problem in impeller blades of PA fan and Seal Air fan which were rectified at site. Turning gear of generator were mismatched which took a larger time to rectify. Coupling bolt of generator shaft and turbine shaft were mismatched.

Table 3.33: Problems/Challenges faced in O&M after R&M Implementation at Unit-5 Bandel TPS

S. No.	Area	Problems / Challenges faced after implementation of R&M interventions	Remedial Measures Taken / Suggested
i.	**Boiler**		
	Coal Mills	Coal Feeder: Frequent tripping occurred due to clean out conveyor flight (cantilever type support) bend. Problem faced in Dynamic Classifier due to overload tripping.	WBPDCL/DPSI jointly working on the matter.
	Air Preheater	Abnormal vibration and sound observed in FD fan discharge duct to APH when both FD fans were running.	Additional stiffeners introduced inside duct during this shut-down w.e.f. 17.06.2016. At

			present trouble resolved.
	ID Fans, FD Fans & PA Fans	ID & FD fan performance satisfactory, however PA fan vibration problem occurred initially which is now resolved.	
ii.	**Turbine**	Bearing No. 2 vibration high but within the tripping value during coasting down of the turbine but in normal running condition vibration of all bearing are within the limit.	
	HP Heater	FW side safety valve passing.	
	LP Heater	Water box top flange leakage.	
iii.	**Ash Handling System**	Ash handling plant performance is satisfactory when desired quality of coal being burnt. Fly ash evacuation in dry mode is satisfactory.	
iv.	**C&I Systems**	Boiler and Turbine parameters do not match exactly. Turbine follow mode operation is not satisfactory. Flame scanning system does not work well in the front fire boiler. Choice of instrument operating range is not perfect in few areas. Lack of perfection in the designing level causes problem in implementing modern control concept like ATRS & CMC etc.	
v.	**Pollution Control**	Emission level is maintained within limit when desired quality of coal being burnt.	

G. PG Test

PG test of the unit was done on 21st November, 2016 and the unit achieved the guaranteed values of Gross Power Output, Gross Unit Heat Rate, APC and SPM level as mentioned in the Table 3.30.

I. Reasons for Satisfactory/Unsatisfactory Performance

The operation performance of newly installed turbine and generator found satisfactory along with the newly installed DCS system which improved the monitoring of plant parameters easier and reliable.

While the above equipment are performing good but some of the following equipment are performing unsatisfactory. The quality and performance of equipment like Starting Ejector, Balluf feedback transmitter, Low NO_x burner and PA fan are not up to the mark. Insulation and cladding of critical pipes are not satisfactory and Ash evacuation capacity remains same as earlier.

J. Overall Comments

Although the unit was tested at the load of 186MW for the achievement of target values on 09th May, 2016 after implementation of R&M works for different parameters such as Heat

Rate, Specific Oil Consumption, Specific Coal Consumption, SPM level and Turbine Efficiency but still after implementation of R&M the performance has not increased significantly.

3.8 Unit-6 (1x210 MW) Koradi TPS, MSPGCL, Maharashtra

A. Background of the Project:

Since its commissioning, KTPS saw expansion in stages. First unit of 115 MW began in 1974. Later, three more units each of 115 MW, were added between 1975 and 1976 while 200 MW unit was added in 1978. Two more units, of 210 MW each, between 1982 and 1983. Unit#6 of Koradi Thermal Power Station is a 210 MW unit commissioned in the year 1982. The boiler is BHEL design and turbine is LMZ design manufactured by BHEL. Though the boiler was originally designed for coal with gross calorific value (GCV) of 5000 kCal/kg, it operates, presently, on coal with GCV in the region of 3400 kCal/kg. The boiler efficiency is 81.64%. The performance data up to 2006-07 indicates that the output from Unit #6 has been declining and it is now operating well below its original designed performance level.

R&M works consisting of four major packages i.e. BTG, Electrical and BOP are under progress. The project will be completed in 27 months with a shutdown period of 6 Months. Zero date of R&M project was 03rd March, 2014 which was started as per schedule. The anticipated month of synchronization was April, 2016 which got delayed and the new synchronization schedule is in February, 2017. Detailed activity schedule was submitted by the contractor M/s. BHEL after finalization of their sub-contractors, which is being followed for monitoring purpose. BOP contractor was terminated due to non-execution of project and fresh tenders were floated for four packages. For three packages Letter of Award (LOA) was issued and the fourth package finalization is under progress. Hence, Post R&M performance data of unit cannot be given at this stage.

B. Brief Scope of R&M Works

i. Main Plant (BTG) Package:

Supply & Installation of following items. Renovation package of Boiler, Turbine, Generator and Control and Instrumentation systems for increased life and efficiency. Boiler Re-engineering for lowered coal CV, Milling Plant & ESP up gradation. Turbine replacement with reaction design, C&I up gradation with DCS Cooling Towers, compressors and refurbishment etc.

ii. Balance of Plant (BOP) Package:

Cooling Towers and Cooling Water System- Refurbishment and enhanced cooling range, Raw Water System- Replacement of one RW Pump for energy efficiency and water conservation, DM and Pre Treatment System, Addition of activated carbon filter in the stream & refurbishment, Compressed Air System- replacement of five instruments air compressors, Ash Handling System – Interfacing with new ESP and valves replacement, and Fire Fighting System - New inert gas system for PCR & New fire sensing devises for Cable galleries. Raw water system, Coal Handling Plant and Compressed Air system packages were deleted from earlier scope of BOP package. However, the same was appearing in the draft report. New ESP is under Construction and the SPM level is envisaged below 71 mg/Nm^3.

iii. Electrical Package:

Supply and installation of Unit Auxiliary Transformer, 6.6kV System, HT and LT motors, LT system, Energy meter, HT and LT power cable, Bus Transfer Device, Efficient illumination system, control cables and DCS control for 210MW unit-6 of KTPS, Koradi. Electrical package work was interlinked with BTG package and as such it was affected by delay in the schedule of BTG package. Capacity uprating of Generator with new one of 268 MVA capacity along with new Generator Transformer (285MVA) and Unit Auxiliary Transformer (25 MVA) is being done. 38 Vacuum Circuit Breaker (VCB), 64 LT motors, 13 LT air circuit breakers will be replaced under Electrical package.

C. Performance Parameters

Table 3.34: Koradi Unit-6 Performance Parameters

Parameters	Pre R&M			
	2004-05	**2005-06**	**2006-07**	**2007-08**
PLF (%)	68.11	68.28	71.86	67.39
APC (%)	9.93	9.64	9.95	10.42
SOC (ml/kWh)	2.40	2.67	2.74	3.50
SCC (kg/kWh)	0.77	0.76	0.81	0.84
Heat Rate (kCal/kWh)	2955	2977	2997	3081

Table 3.35: Unit-6 Koradi TPS Environmental Performance

S. No.	Environment Parameters	Before R&M/LE	Target Value of R&M/LE	Actual after R&M/LE
i.	SPM Level (mg/Nm^3)	NA	70	New ESP under installation
ii.	SO_x (mg/m^3)	NA	--do--	NA
iii.	NO_x (mg/m^3)	NA	--do--	NA

Review of Pre R&M data, above, shows that units PLF is low, Auxiliary Power Consumption is high along with Specific Oil Consumption and Specific Coal Consumption. The Heat Rate is also is also on higher side as compared to the designed value of 2397 kCal/kWh.

Chapter-4

Analysis of Post R&M Experience in O&M

4.1 Review of Post-R&M Experience in O&M

Performance of Thermal Unit mainly measured in terms of operating parameters such as Gross Generation, Heat Rate, PLF, Auxiliary Power Consumption, Specific Oil Consumption, Specific Coal Consumption etc. Performance of the units Post R&M utility wise has been given and analyzed and reviewed as under:

4.1.1 Peak Output (MW)

Table 4.1: Peak Generation in MW Pre and Post R&M

TPS	Pre R&M 1st Year (MW)	Pre R&M 2nd Year (MW)	Post 1st Year (MW)	Difference (MW)	% Improvement
U-3 GNDTP	98	95	125	27	21.60
U-4 GNDTP	92	87	124	32	25.80
U-7 Barauni	50	50	109.3	59.3	54.25
U-5 Bandel	205	195	225	20	8.88

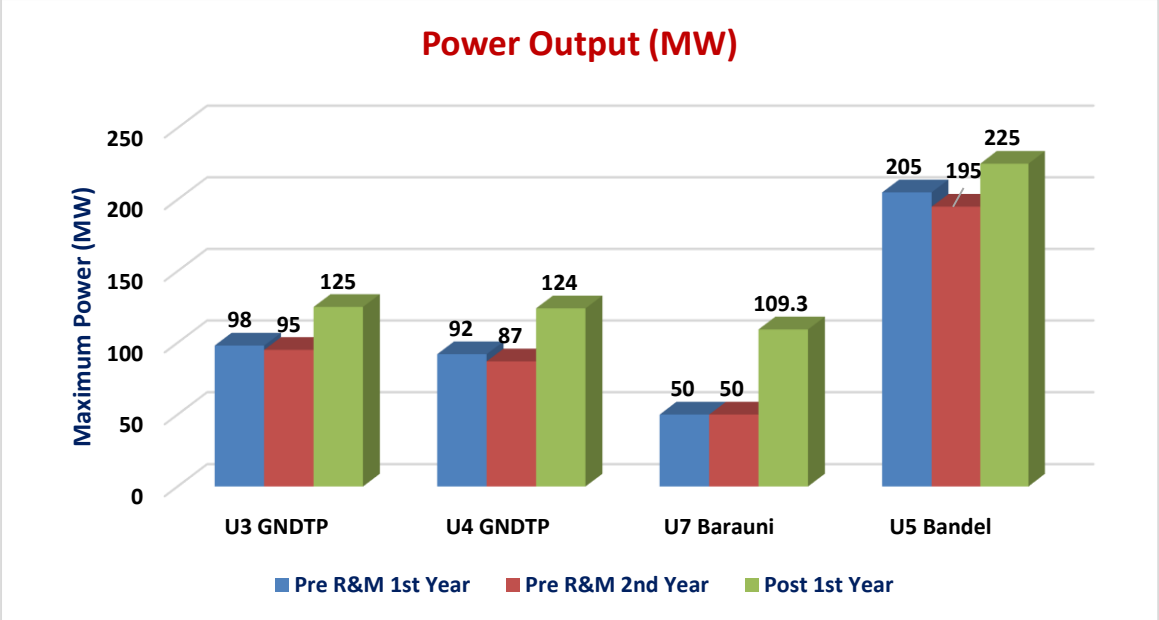

Figure 4.1: Peak Output Pre and Post R&M

From the above trend, it is observed that there is remarkable improvement of Peak Output of Barauni TPS. In case of both the units of GNDTP, satisfactory improvement is achieved in Peak Output (MW).

4.1.2 Gross Power Generation (MU)

For quantitative analysis of Pre and Post Power Generation of the units, comparison is being made on the basis of units generated during a period of the full years immediately before the year of starting R&M works as well as after completing R&M works.

Table 4.2: Analysis of Gross Power Generation values

TPS/UNIT	Maximum Generation recorded over a year		Benefits achieved Post R&M	
	Pre-R&M (MU)	Post-R&M (MU)	Difference (MU)	%
Ukai # 1	573.23	694.32	+ 121.09	17.44
Ukai # 2	569.59	670.01	+ 100.42	14.98
Amarkantak#1	544.29	616.33	+ 72.04	11.68
Amarkantak#2	566.60	657.43	+ 90.83	13.81
Obra # 9	936.12	1557.80	+621.68	39.90
Obra # 10	964.05	308.19	-655.86	-212.81
GNDTP # 3	693.8	570.10	-123.7	-21.69
GNDTP # 4	622.58	199.28	-423.3	-212.41
KBUNL # 1	Data not available	687.20	NA	NA
Barauni # 7	140.8	57.57	-83.23	-144.57
Bandel # 5	1066.98	776.11	-290.87	-37.47
Koradi # 6	Data not available	R&M still under progress.		

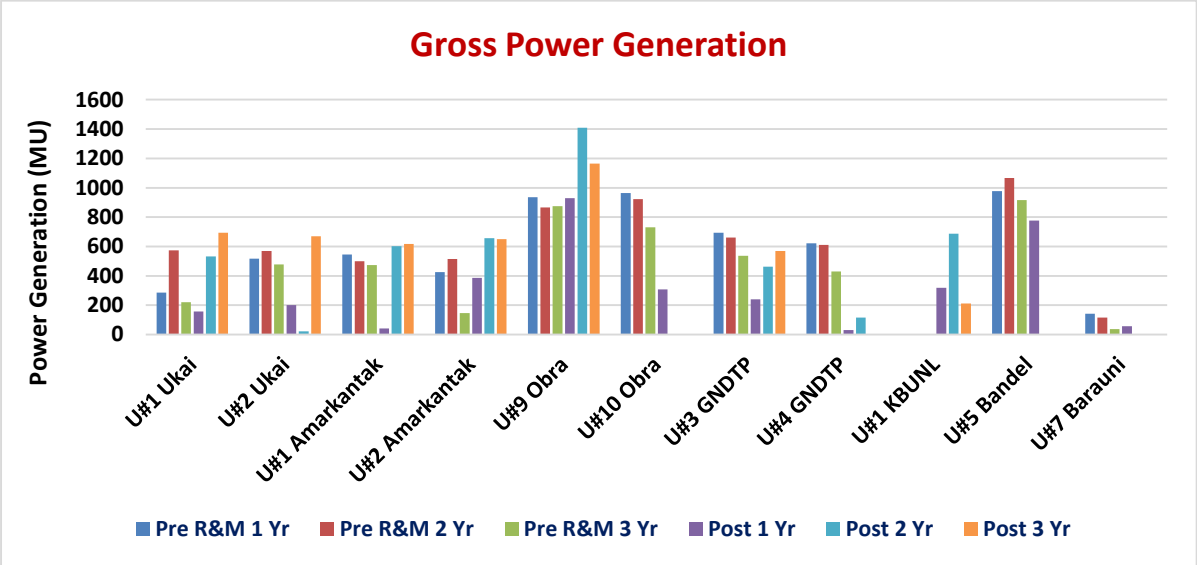

Fig. 4.2: Comparative Analysis of Gross Power Generation before and after R&M

The Pre and Post R&M gross power generation of respective units as indicated in above graph, are detailed below:

i. Ukai TPS

a) Unit No. 1:

The Pre R&M maximum Generation of this unit during the year 2005-06 was 573.23 MU and after completion of R&M works, it increased to 694.32 MU during the year 2010-11, showing an increase of 17.44%.

b) Unit No. 2:

The Pre R&M maximum Generation of the unit during 2005-06 was 569.59 MU and after completing the R&M works, it increased to 670.01 MU during the year 2010-11, showing an increase of 14.98%.

ii. Amarkantak TPS

a) Unit No. 1:

The Pre R&M maximum Generation of this unit during 2007-08 was 544.29 MU and after completion of R&M works, it increased to 616.23MU during the year 2013-14 showing an increase of 11.68%.

b) Unit No. 2:

The Pre R&M maximum Generation of this unit during 2008-09 was 566.60 MU and after completion of R&M works, it increased to 657.43 MU during the year 2012-13 showing an increase of 13.81%.

iii. Obra TPS

a) Unit No. 9:

The Pre R&M maximum Generation of this unit during 2005-06 was 936.12 MU and after completion of R&M works, it increased to 1557.8 MU during 2014-15 showing an increase of 39.90%.

b) Unit No. 10:

The Pre R&M maximum Generation of this unit during 2009-10 was 964.05 MU and after completion of R&M works during the period April to December 2016 it was 308.19 MU showing a decrease of 212.81%.

iv. GNDTP

a) Unit No. 3:

The Pre R&M maximum Generation of this unit during 2007-08 was 693.80 MU which decreased to 570.10 MU during the year 2014-15 after completion of R&M works showing a decrease of 21.69%.

b) Unit No. 4:

The Pre R&M maximum Generation of this unit during the 2008-09 was 622.58 MU and after completion of R&M works during the year 2015-16, it was 199.28 MU, showing a decrease of 212.41%. The generation was low as unit was not running continuously, the reason of which has not been provided by the plant authorities. As such the comparison has not been made.

v. Unit No. 1 Muzaffarpur TPS (KBUNL):

Since the unit was under shutdown from 06th October, 2003, as such no Pre R&M data was made available. However, R&M works were carried with a very long delay from 15th April, 2010 to 05th July, 2013. The Post R&M data made available gives Gross Generation as 687.20 MU during the year 2014-15. In this case also the comparison cannot be made.

vi. Unit No. 7 Barauni TPS:

The Pre R&M Generation of this unit during the year 2003-04 was 140.80 MU which decreased to 57.57 MU, showing a decrease of 144.57%.

vii. Unit No. 5 Bandel TPS:

The Pre R&M maximum Generation of this unit during the year 2011-12 was 1066.98 MU and after completion of R&M works till Dec, 2016 it was 776.11, showing a decrease of 37.47%.

viii. Unit No. 6 Koradi TPS:

R&M works are still under progress. As such no comparison can be made.

In case of Ukai, Amarkantak and Obra unit-9 there was an increase in gross power generation and in case of Obra unit-10, Bandel TPS, GNDTP and Barauni TPS there was decrease in power generation Post R&M.

4.1.3 Plant Load Factor (PLF)

For quantitative analysis of Pre and Post PLF of the units, comparison is being made on the basis of unit's availability during the full year immediately before the year of starting R&M works with full year after the year of completing R&M works.

Table 4.3: Analysis of PLF Pre and Post R&M

TPS/UNIT	Maximum PLF recorded over a year		Benefits Accrued
	Pre-R&M (%)	Post-R&M (%)	Difference (%)
Ukai # 1	27.15	66.05	38.90
Ukai # 2	54.18	63.78	9.6
Amarkantak#1& 2	52.74	60.18	7.44
Obra # 9	53.43	88.92	35.49
Obra # 10	55.03	41.92	-13.11
GNDTP # 3	71.8	54.23	-17.57
GNDTP # 4	64.61	18.91	-45.7
KBUNL # 1	Data not available.	80.05	
Barauni # 7	15.26	17.15	1.89
Bandel # 5	57.82	54.66	-3.16
Koradi	71.86	R&M in progress	

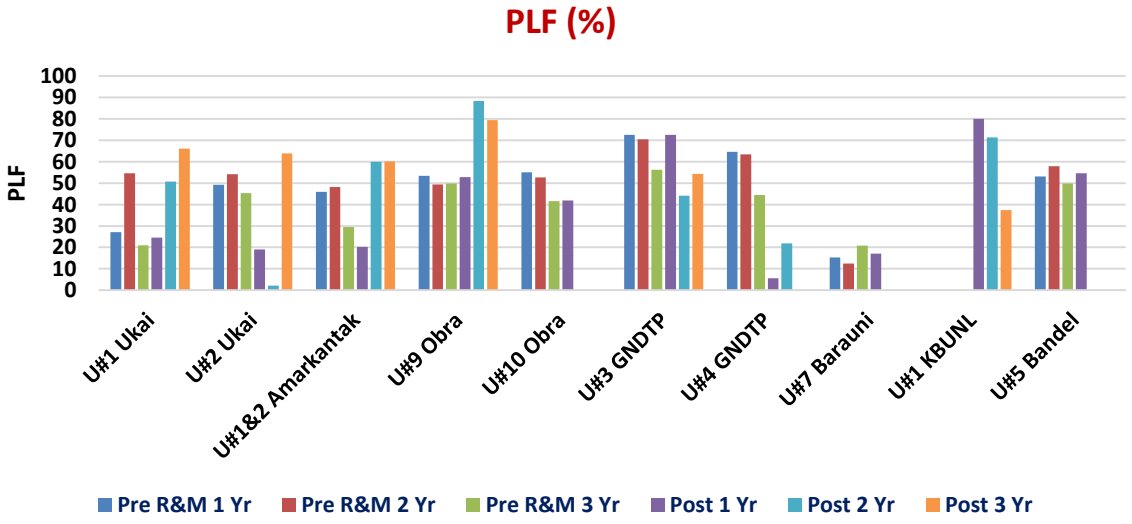

Fig. 4.3: Comparative Analysis of PLF before and after R&M

The Pre and Post R&M PLF of respective units as indicated in above graph, are detailed below:

i. Ukai TPS

a) Unit No. 1:

The Pre R&M PLF of this unit during the year 2005-06 was 27.15% and after completion of R&M works, it increased to 66.05% during the year 2010-11 Post R&M, showing an increase in PLF by 38.90%.

b) Unit No. 2:

The Pre R&M PLF of the unit during 2005-06 was 54.18% and after completing the R&M works, it increased to 63.78% during the year 2010-11, showing an increase in PLF by 9.60%.

ii. Amarkantak TPS Unit-1 & 2

Unit No. 1 & 2:

The Pre R&M PLF of this unit during the year 2006-07 was 52.74% and after completion of R&M works, it increased to 60.18% during the year 2013-14, showing an increase in PLF by 7.44%.

iii. Obra TPS

a) Unit No. 9:

The Pre R&M PLF of this unit during the year 2005-06 was 53.43% and after completion of R&M works, it increased to 88.92% during the year 2014-15, showing an increase in PLF by 35.49%.

b) Unit No. 10:

The Pre R&M PLF of this unit during the year 2009-10 was 55.03% and after completion of R&M works PLF achieved was 41.92% in 2016-17, showing a decrease in PLF by 13.11%.

iv. GNDTP

a) Unit No. 3:

The Pre R&M PLF of this unit during the year 2007-08 was 71.80% which decreased to 54.23% during the year 2014-15 after completion of R&M works, showing a decrease in PLF by 17.57%.

b) Unit No. 4:

The Pre R&M PLF of this unit during the year 2008-09 was 64.61% and after completion of R&M works during the year 2015-16, it was 18.91%, showing a decrease of 45.70%. The PLF was low as unit was not running continuously, the reason of which has not been provided by the plant authorities. As such no comparison can be made.

v. Unit No. 1 Muzaffarpur TPS (KBUNL):

Since the unit was under shutdown from 06th October, 2003, as such no Pre R&M data was made available. However, R&M works were carried out with a very long delay from 15th April, 2010 to 05th July, 2013. The Post R&M data made available gives PLF as 80.05% during the year 2013-14, as such no comparison can be made.

vi. Unit No. 7 Barauni TPS:

The Pre R&M PLF of this unit during the year 2003-04 was 15.26% after completion of R&M works, it was 17.15% in 2016-17, showing an increase in PLF by 1.89%.

vii. Unit No. 5 Bandel TPS:

The Pre R&M PLF of this unit during the year 2011-12 was 57.82% and after completion of R&M works, it was 54.66% in 2016-17, showing a decrease in PLF by 3.16%.

ix. Unit No. 6 Koradi TPS:

R&M works are still under progress. As such no comparison can be made.

From the above, it can be seen that PLF of Ukai, Amarkantak, Obra unit-9 and Barauni TPS increased but in case of Obra unit-10, GNDTP, Bandel and KBUNL TPS PLF decreased after R&M works.

4.1.4 Auxiliary Power Consumption (APC)

For quantitative analysis of Pre and Post APC of the units, comparison is being made on the basis of unit's APC during the full year immediately before the year of starting R&M works with full year after the year of completing R&M works.

Table 4.4: Analysis of APC Pre and Post R&M

TPS/UNIT	Lowest APC recorded over a year		Benefits Accrued
	Pre-R&M (%)	Post-R&M (%)	Difference (%)
Ukai # 1	08.91	10.85	1.94
Ukai # 2	09.38	10.82	1.44
Amarkantak#1&2	11.71	9.46	-2.25
Obra # 9	11.75	9.30	-2.45
Obra # 10	11.84	11.48	-0.36
GNDTP # 3	11.4	10.71	-0.69
GNDTP # 4	12.36	10.72	-1.64
KBUNL # 1	Data not available.	11.32	NA
Barauni # 7	16.37	12	-4.37
Bandel # 5	11.54	12.08	0.54
Koradi	9.64	R&M in progress	

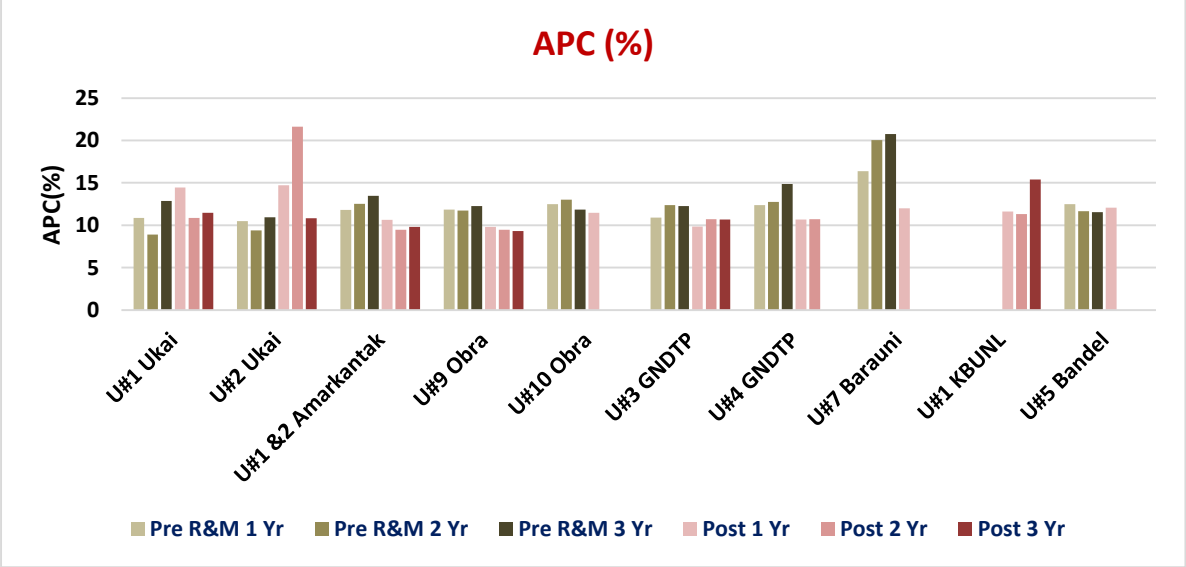

Fig. 4.4: Comparative Analysis of Auxiliary Power Consumption before and after R&M

The Pre and Post R&M APC of respective units as indicated in above graph, are detailed below:

i. Ukai TPS

a) Unit No. 1:

The Pre R&M APC of this unit during the year 2005-06 was 8.91% and after completion of R&M works, it was recorded as 10.85% during the year 2009-10 after R&M, showing an increase in APC by 1.94%.

b) Unit No. 2:

The Pre R&M APC of the unit during 2005-06 was 9.38% and after completing the R&M works, it was 10.82% during the year 2010-11, showing an increase in APC by 1.44%.

ii. Unit No. 1 & 2 Amarkantak TPS:

The Pre R&M APC of the units during the year 2006-07 was 11.71% and after completion of R&M works, it was 9.46% during the year 2012-13, showing an improvement in APC by 2.25%.

iii. Obra TPS

a) Unit No. 9:

The Pre R&M APC of this unit during the year 2006-07 was 11.75% and after completion of R&M works, it was 9.30% during the year 2013-14 after R&M, showing improvement in APC by 2.45%.

b) Unit No. 10:

The Pre R&M APC of this unit during 2011-12 was 11.84% and after completion of R&M works, it was 11.48% during the year 2016-17 after R&M, showing improvement in APC by 0.36%.

iv. GNDTP

a) Unit No. 3:

The Pre R&M APC of this unit during the year 2007-08 was 11.40% which decreased to 10.71% during the year 2014-15 after completion of R&M works, showing an improvement in APC by 0.69%.

b) Unit No. 4:

The Pre R&M APC of this unit during the year 2008-09 was 12.36% and after completion of R&M works during the year 2015-16, it was 10.72% showing an improvement in APC by 1.64%.

v. Unit No. 1 Muzaffarpur TPS (KBUNL):

Since the unit was under shutdown from 06th October, 2003, as such no Pre R&M data was made available. However, R&M works were carried out with a very long delay from 15th April, 2010 to 05th July, 2013. The Post R&M data made available gives APC as 11.32% during the year 2014-15, since no Pre R&M data is available therefore, comparison cannot be made.

vi. Unit No. 7 Barauni TPS:

The Pre R&M APC of this unit during full year 2003-04 was 16.37% and after completion of R&M works, it was 12% during the year 2016-17 after R&M, showing improvement in APC by 4.37%.

vii. Unit No. 5 Bandel TPS:

The Pre R&M APC of this unit during the year 2012-13 was 11.54% and after completion of R&M works, it was 12.08% during the year 2016-17 after R&M, showing decrease in APC by 0.54%.

viii. Unit No. 6 Koradi TPS:

R&M works are still under progress. As such no comparison can be made.

From the above, it can be seen that there has been improvement in APC of Amarkantak, Obra, GNDTP, and Barauni units but Ukai TPS and Bandel has shown increase in APC.

4.1.5 Specific Oil Consumption (SOC)

For quantitative analysis of Pre and Post SOC of the units, comparison is being made on the basis of unit's SOC during the full year immediately before the year of starting R&M works with full year after the year of completing R&M works.

Table 4.5: Analysis of SOC Pre and Post R&M

TPS/UNIT	Lowest SOC recorded over a year		Benefits Accrued
	Pre-R&M (ml/kWh)	Post-R&M (ml/kWh)	Difference (ml/kWh)
Ukai # 1	1.02	8.08	7.06
Ukai # 2	3.28	07.38	4.1
Amarkantak#1&2	2.88	1.92	-0.96
Obra # 9	3.13	1.42	-1.71
Obra # 10	1.30	9.33	8.03
GNDTP # 3	1.77	1.44	-0.33
GNDTP # 4	4.74	3.42	-1.32
KBUNL # 1	Data not available.	2.51	NA
Barauni # 7	16.27	29.64	13.37
Bandel # 5	4.01	5.22	1.21
Koradi	2.67	R&M still under progress.	

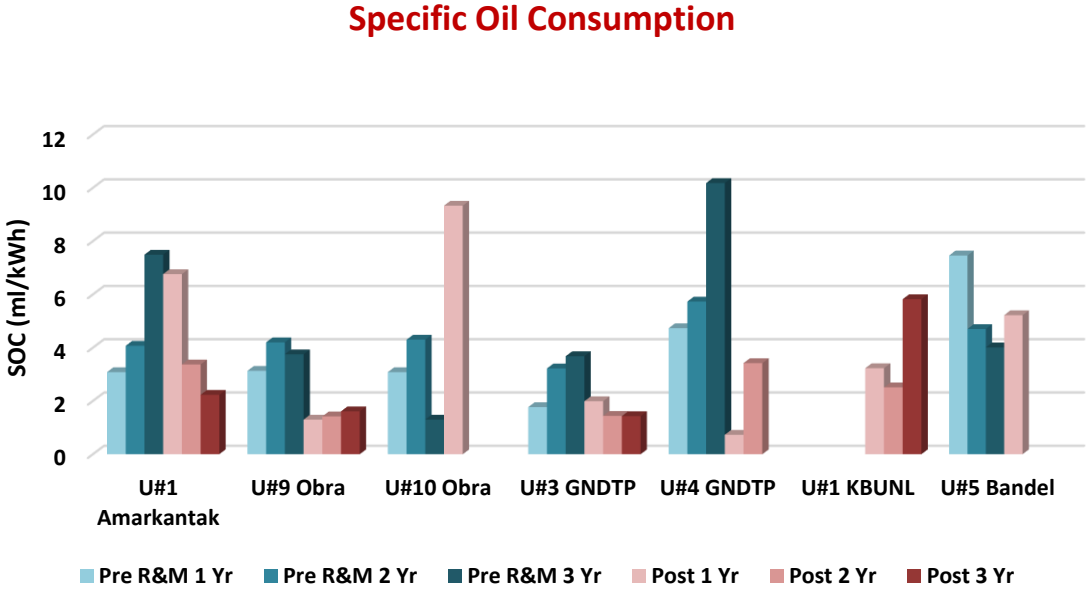

Fig. 4.5 (a): Comparative Analysis of SOC Pre and Post R&M

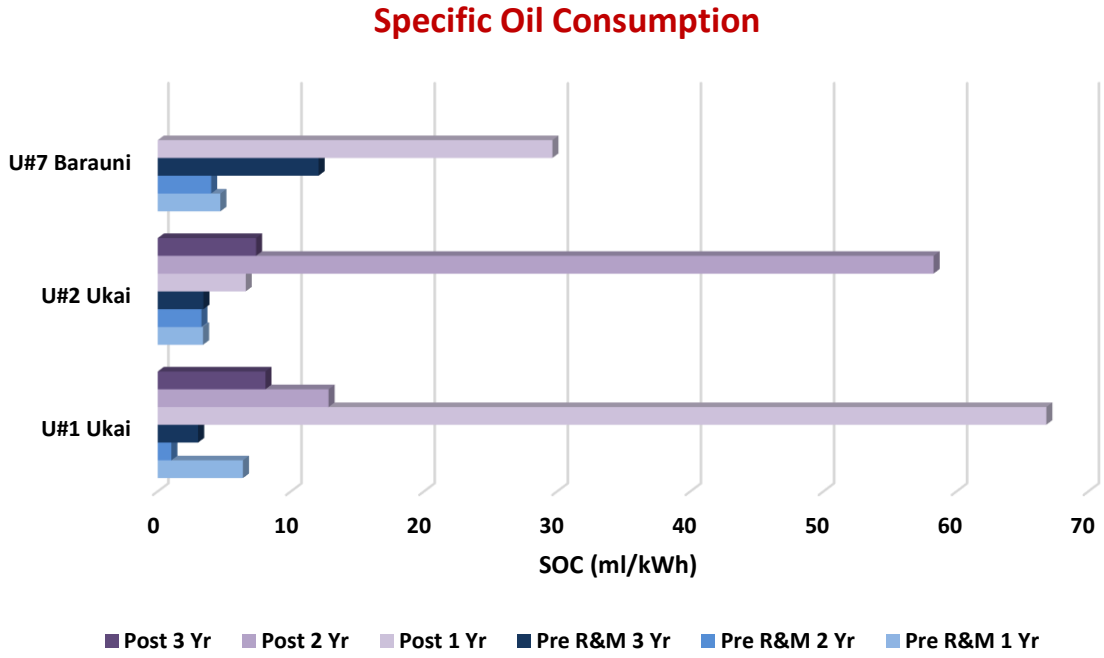

Fig. 4.5 (b): Comparative Analysis of SOC Pre and Post R&M

The Pre and Post R&M SOC of respective units as indicated in above graph, are detailed below:

i. Ukai TPS

a) Unit No. 1:

The Pre R&M SOC of this unit during the year 2005-06 was 1.02 ml/kWh and after completion of R&M works, it was recorded as 8.08 ml/kWh during the year 2010-11 after R&M, showing an increase in SOC by7.06 ml/kWh.

b) Unit No. 2:

The Pre R&M SOC of the unit during 2005-06 was 3.28 ml/kWh and after completing the R&M works, it was 7.38 ml/kWh during the year 2010-11, showing an increase in SOC by 4.1 ml/kWh.

ii. Unit No. 1 & 2 Amarkantak TPS:

The Pre R&M SOC of the units during the year 2006-07 was 2.88 ml/kWh and after completion of R&M works, it reduced to 1.92 ml/kWh during the year 2014-15 Post R&M, showing an improvement in SOC by 0.96 ml/kWh.

iii. Obra TPS

a) Unit No. 9:

The Pre R&M SOC of this unit during 2005-06 was 3.13 ml/kWh and after completion of R&M works, it reduced to 1.30 ml/kWh during the year 2011-12 Post R&M, showing an improvement in SOC of by 1.71 ml/kWh.

b) Unit No. 10:

The Pre R&M SOC of this unit during 2011-12 was 1.30 ml/kWh and after completion of R&M works, it increased to 9.33 ml/kWh during the year 2016-17 Post R&M, showing an increase in SOC by 8.03 ml/kWh.

iv. GNDTP

a) Unit No. 3:

The Pre R&M SOC of this unit during full year 2007-08 was 1.77 ml/kWh which decreased to 1.44 ml/kWh during the year 2014-15 after completion of R&M works, showing an improvement in SOC by 0.33 ml/kWh.

b) Unit No. 4:

The Pre R&M SOC of this unit during full year 2008-09 was 4.74 ml/kWh and after completion of R&M works during the year 2015-16, it was 3.42 ml/kWh, showing an improvement in SOC by 1.32 ml/kWh.

v. Unit No. 1 Muzaffarpur TPS (KBUNL):

Since the unit was under shutdown from 06th October, 2003, as such no Pre R&M data was made available. However, R&M works were carried out with a very long delay from 15th April, 2010 to 05th July, 2013. The Post R&M data made available gives SOC as 2.51 ml/kWh during the year 2014-15, comparison could not be made because of non-availability of Pre R&M data.

vi. Unit No. 7 Barauni TPS:

The Pre R&M SOC of this unit during 2004-05 was 16.27 ml/kWh and after completion of R&M works, it was 29.64 ml/kWh during the year 2016-17 after R&M, showing an increase in SOC by 13.37 ml/kWh.

vii. Unit No. 5 Bandel TPS:

The Pre R&M SOC of this unit during full year 2012-13 was 4.01 ml/kWh and after completion of R&M works, SOC achieved was 5.22 ml/kWh showing an increase in SOC by 1.21 ml/kWh.

viii. Unit No. 6 Koradi TPS:

R&M works are still under progress. As such no comparison can be made.

From the above, it may be observed that SOC increased in Ukai, Obra unit-10, Barauni and Bandel units but it decreased for Amarkantak, Obra unit-9 and GNDTP.

4.1.6 Specific Coal Consumption (SCC)

For quantitative analysis of Pre and Post SCC of the units, comparison is being made on the basis of unit's SCC during the full year immediately before the year of starting R&M works with full year after the year of completing R&M works.

Table 4.6: Analysis of SCC Pre and Post R&M

TPS/UNIT	Lowest SCC recorded over a year		Benefits achieved Post R&M
	Pre-R&M (kg/kWh)	Post-R&M (kg/kWh)	Difference (kg/kWh)
Ukai # 1	0.67	0.54	-0.13
Ukai # 2	0.66	0.56	-0.1
Amarkantak#1&2	0.77	0.76	-0.01
Obra # 9	0.86	0.78	-0.08
Obra # 10	0.85	0.85	0
GNDTP # 3	0.734	0.617	-0.117
GNDTP # 4	0.747	0.696	-0.051

KBUNL # 1	Data not available	0.761	NA
Barauni # 7	1.07	0.79	-0.28
Bandel # 5	0.84	0.693	-0.147
Koradi	0.76	R&M still under progress	

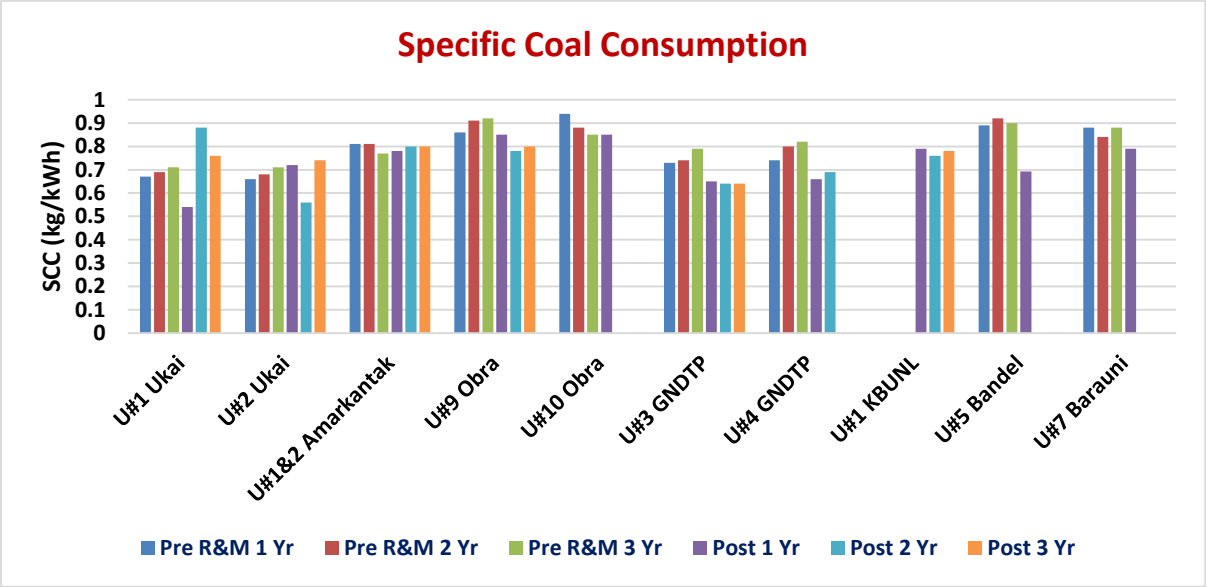

Fig. 4.6: Comparative Analysis of SCC Pre and Post R&M

The Pre and Post R&M SCC of respective units as indicated in above graph, are detailed below:

i. Ukai TPS

a) Unit No. 1:

The Pre R&M SCC of this unit during 2004-05 was 0.67 kg/kWh and after completion of R&M works, it was recorded as 0.54 kg/kWh during the year 2010-11 Post R&M, showing improvement in SCC by 0.13 kg/kWh.

b) Unit No. 2:

The Pre R&M SCC of the unit during 2004-05 was 0.66 kg/kWh and after completing the R&M works, it was 0.56 kg/kWh during the year 2009-10, showing an improvement in SCC by 0.1 kg/kWh.

ii. Unit No. 1 & 2 Amarkantak TPS:

The Pre R&M SCC of the units during full year 2009-10 was 0.77 kg/kWh and after completion of R&M works, it was 0.76 kg/kWh during the year 2014-15 after R&M, showing an improvement in SCC by 0.01 kg/kWh.

iii. Obra TPS

a) Unit No. 9:

The Pre R&M SCC of this unit during full year 2005-06 was 0.86 kg/kWh and after completion of R&M works, it was 0.78 kg/kWh during the year 2012-13 after R&M, showing an improvement in SCC by 0.08 kg/kWh.

b) Unit No. 10:

The Pre R&M SCC of this unit during 2011-12 was 0.85 kg/kWh and after R&M in 2016-17, it was 0.85 kg/kWh.

iv. GNDTP

a) Unit No. 3:

The Pre R&M SCC of this unit during 2007-08 was 0.734 kg/kWh which decreased to 0.617 kg/kWh during the year 2013-14 after completion of R&M works, showing an improvement in SCC by 0.117 kg/kWh.

b) Unit No. 4:

The Pre R&M SCC of this unit during full year 2008-09 was 0.747 kg/kWh and after completion of R&M works during the year 2015-16, it decreased to 0.696 kg/kWh, showing an improvement in SCC by 0.051 kg/kWh.

v. Unit No. 1 Muzaffarpur TPS (KBUNL):

Since the unit was under shutdown from 06th October, 2003, as such no Pre R&M data was made available. However, R&M works were carried out with a very long delay from 15th April, 2010 to 05th July, 2013. The Post R&M data made available gives SCC as 0.761 kg/kWh during the year 2014-15. As no Pre R&M data is available, so no comparison could be established.

vi. Unit No. 7 Barauni TPS:

The Pre R&M SCC of this unit during full year 2004-05 was 1.07 kg/kWh and after completion of R&M works during the year 2016-17, it decreased to 0.79 kg/kWh, showing an improvement in SCC by 0.28 kg/kWh.

vii. Unit No. 5 Bandel TPS:

The Pre R&M SCC of this unit during full year 2012-13 was 0.84 kg/kWh and after completion of R&M it was 0.693 kg/kWh, showing an improvement of 0.147 and after completion of R&M works during the year 2015-16, it decreased to 0.696 kg/kWh, showing an improvement in SCC by 0.051 kg/kWh.

viii. Unit No. 6 Koradi TPS:

R&M works are still under progress. As such no comparison can be made.

It is observed that SCC of all the units increased after R&M works.

4.1.7 Heat Rate (kCal/kWh)

For quantitative analysis of Pre and Post Heat Rate of the units, comparison is being made on the basis of unit's Heat Rate during the full year immediately before the year of starting R&M works with full year after the year of completing R&M works.

Table 4.7: Analysis of Heat Rate Pre and Post R&M

TPS/UNIT	Lowest Heat Rate recorded over a year		Benefits achieved Post R&M	
	Pre-R&M (kCal/kWh)	Post-R&M (kCal/kWh)	Difference (kCal/kWh)	% Improvement*
Ukai # 1	2765	2793	28	1
Ukai # 2	2723	2786	63	2.26
Amarkantak# 1&2	3520	3431	-89	-2.59
Obra # 9	3022	2520	-502	-19.92
Obra # 10	2700	2586	-114	-4.4
GNDTP # 3	3084.21	2577.64	-506.57	-19.65
GNDTP # 4	3214.16	2858.69	-355.47	-12.43
KBUNL # 1	NA	2978.82	NA	NA
Barauni # 7	5397.27	NA	NA	NA

Bandel # 5	3007	2285	-722	-31.59
Koradi	2977	R&M still under progress		NA

**Negative values show improvement in Heat Rate*

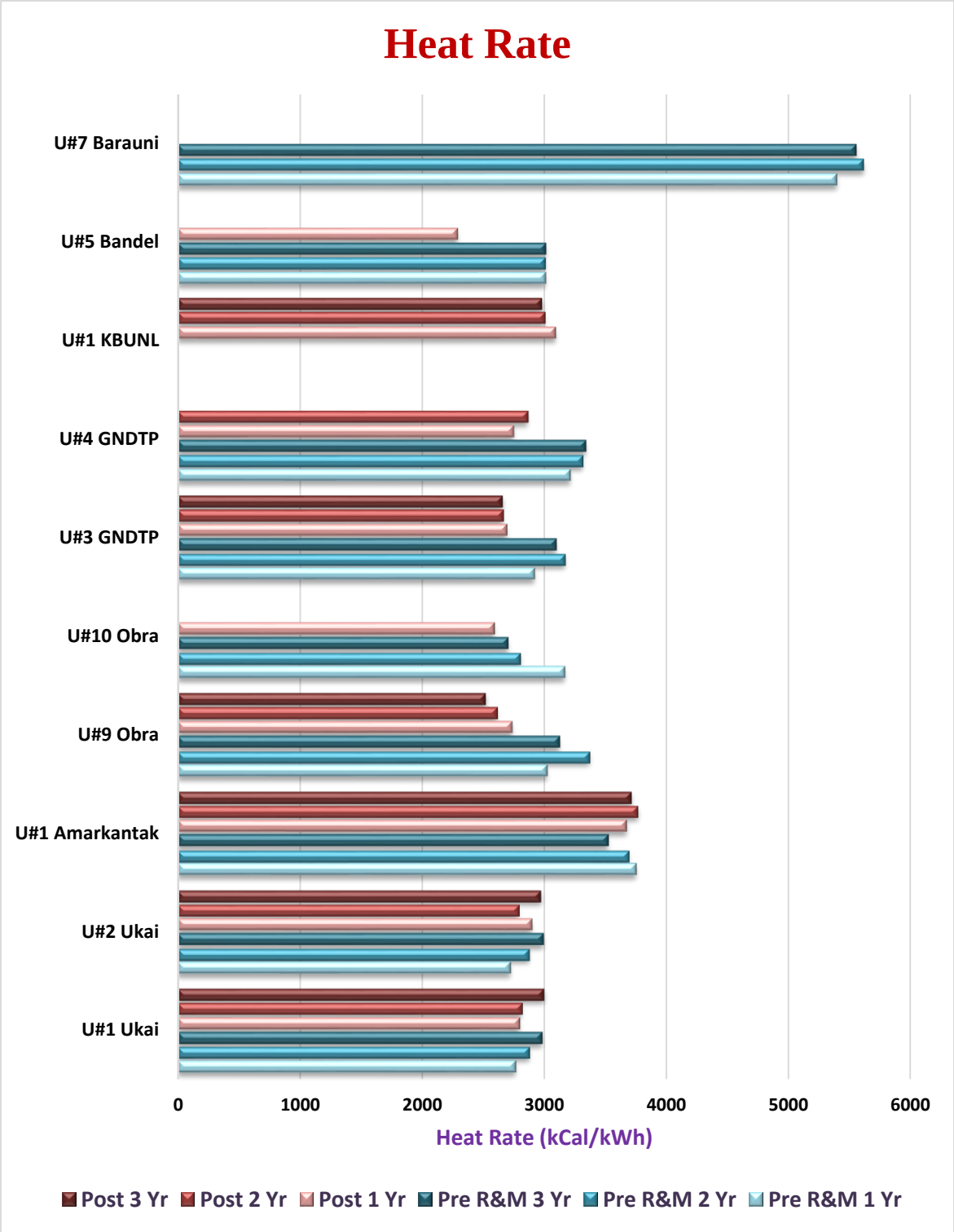

Fig. 4.7: Comparative Analysis of Heat Rate Pre and Post R&M

The Pre and Post R&M Heat Rate of respective units as indicated in above graph, are detailed below:

i. Ukai TPS

a) Unit No. 1:

The Pre R&M Heat Rate of this unit during 2004-05 was 2765 kCal/kWh and after completion of R&M works, it was recorded as 2793 kCal/kWh during the year 2008-09 after R&M, showing an increase of 28 kCal/kWh i.e. the Heat Rate deteriorated.

b) Unit No. 2:

The Pre R&M Heat Rate of the unit during 2004-05 was 2723 kCal/kWh and after completing the R&M works, it was 2786 kCal/kWh during the year 2009-10, showing an increase of 63 kCal/kWh i.e. the Heat Rate deteriorated.

ii. Unit No. 1 & 2 Amarkantak TPS:

The Pre R&M Heat Rate of the units during 2009-10 was 3520 kCal/kWh and after completion of R&M works, it was 3431 kCal/kWh during the year 2014-15 Post R&M, showing improvement of 89 kCal/kWh.

iii. Obra TPS

a) Unit No. 9:

The Pre R&M Heat Rate of this unit during full year 2005-06 was 3022 kCal/kWh and after completion of R&M works, it decreased to 2520 kCal/kWh during 2013-14, showing an improvement of 502 kCal/kWh.

b) Unit No. 10:

The Pre R&M Heat Rate of this unit during full year 2011-12 was 2700 kCal/kWh and after completion of R&M works, it decreased to 2586 kCal/kWh during 2016-17, showing an improvement of 114 kCal/kWh.

iv. GNDTP

a) Unit No. 3:

The Pre R&M Heat Rate of this unit during 2007-08 was 3084.21 kCal/kWh which decreased to 2577.64 kCal/kWh during the year 2013-14 after completion of R&M works, showing an improvement of 506.57 kCal/kWh.

b) Unit No. 4:

The Pre R&M Heat Rate of this unit during 2008-09 was 3214.16 kg/kWh and after completion of R&M works during the year 2015-16, it decreased to 2858.69 kg/kWh, showing an improvement of 355.47 kCal/kWh.

v. Unit No. 1 Muzaffarpur TPS (KBUNL):

Since the unit was under shutdown from 06th October, 2003, as such no Pre R&M data was made available. However, R&M works were carried out with a very long delay from 15th April, 2010 to 05th July, 2013. The Post R&M data made available gives Heat Rate as 2978.82 kCal/kWh during the year 2015-16. As no Pre R&M data is available, as such no comparison made.

vi. Unit No. 7 Barauni TPS:

The Pre R&M Heat Rate of this unit during full year 2003-04 was 5397.27 kCal/kWh and after completion of R&M works in 2016-17, the data was not available since the COD was declared on 04th November, 2016.

vii. Unit No. 5 Bandel TPS:

The Pre R&M Heat Rate of this unit during full year 2012-13 was 3007 kCal/kWh and after completion of R&M works, it decreased to 2285 kCal/kWh during 2016-17, showing an improvement of 722 kCal/kWh.

viii. Unit No. 6 Koradi TPS:

R&M works are still under progress. As such no comparison can be made.

It is observed that except Ukai units- 1&2, Heat Rate has improved for all other units.

4.1.8 Environment Parameters

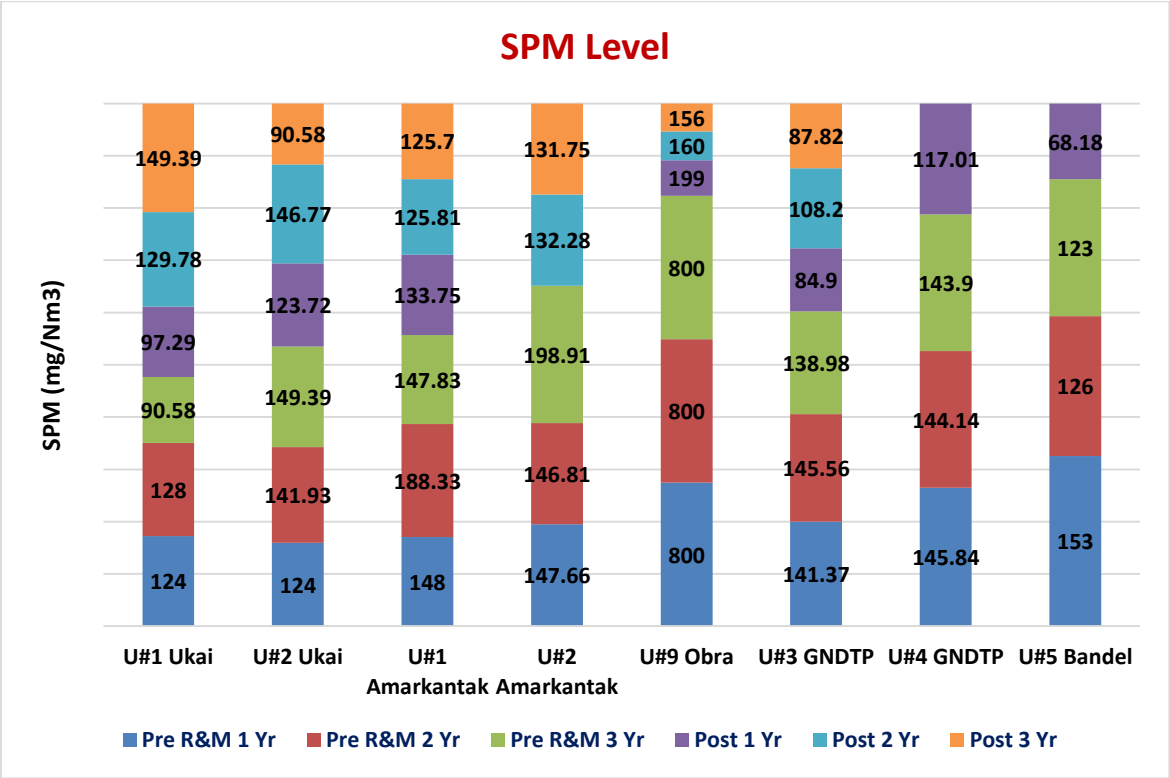

Fig 4.8: Comparative study of SPM Pre and Post R&M

From the above it can be seen that the SPM level of all the units except Ukai#1 have decreased after R&M.

4.2 Reviews

4.2.1 Ukai TPS (2x120 MW)

Unit #1 [R&M works carried out from 12.08.2008 to 24.2.2010 (18 Months)]. Units synchronized on 24.02.2010. Unit #2 [R&M works carried out from 12.08.2008 to 24.2.2010 (18 Months)]. Units synchronized on 24.02.2010. The project got delayed and it was very difficult to get the spares from OEM for operation and maintenance of both units. Following items can be observed from the comparison of performance of the unit, before and after R&M works that.

a) There has been some increase in Gross generation
b) Improvement in P.L.F. but short of expectations as per Design value of 9%
c) Reduction in Aux. Consumption
d) Reduction in Specific oil consumption
e) But increase in Specific Coal consumption
f) No improvement in Turbine Heat rate, which remains much higher than anticipated

i. 120 MW Unit # 2

a) Increase in Gross generation
b) Increase in P.L.F, but short of expectations as per Design value of 9%

c) Not much reduction in Aux. Power Consumption (APC)
d) Reduction in Specific Oil Consumption (SOC)
e) But increase in Specific Coal Consumption (SCC)
f) Not much improvement in Turbine Heat Rate

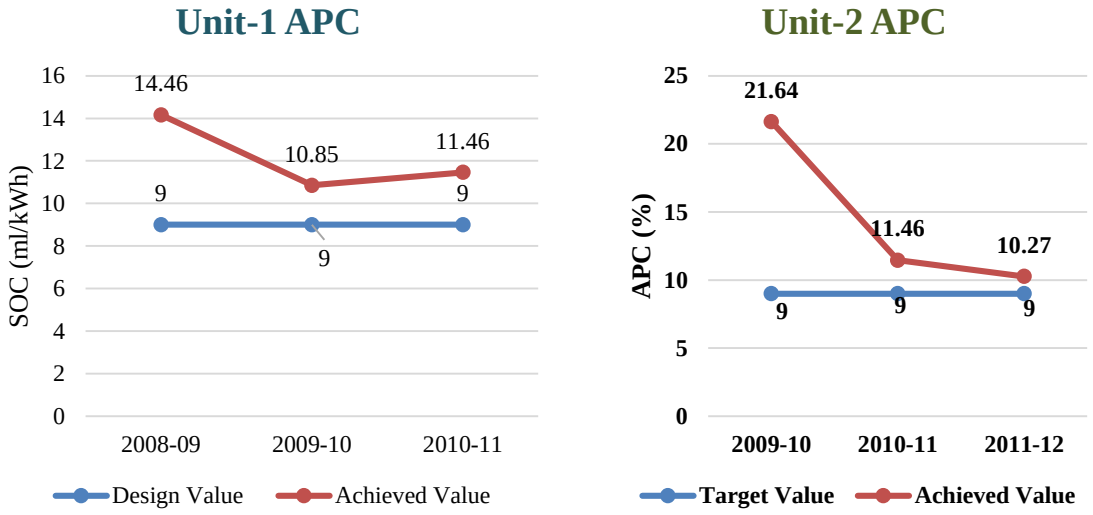

Fig. 4.9: Ukai unit-1 and 2 APC values (Target vs. Achieved) after R&M

The APC of unit 1 was also relatively high (14.16%) in first year after implementation of R&M which dipped to 10.85% in the second year. Then it again rose to 11.46% in third year, which is higher than the designed value. The APC of unit 2 was very high at 21.64% in the first year after R&M then it dipped to 11.46% in second year and it again dropped to 10.27% which was also higher than 9% i.e. the target value of the APC.

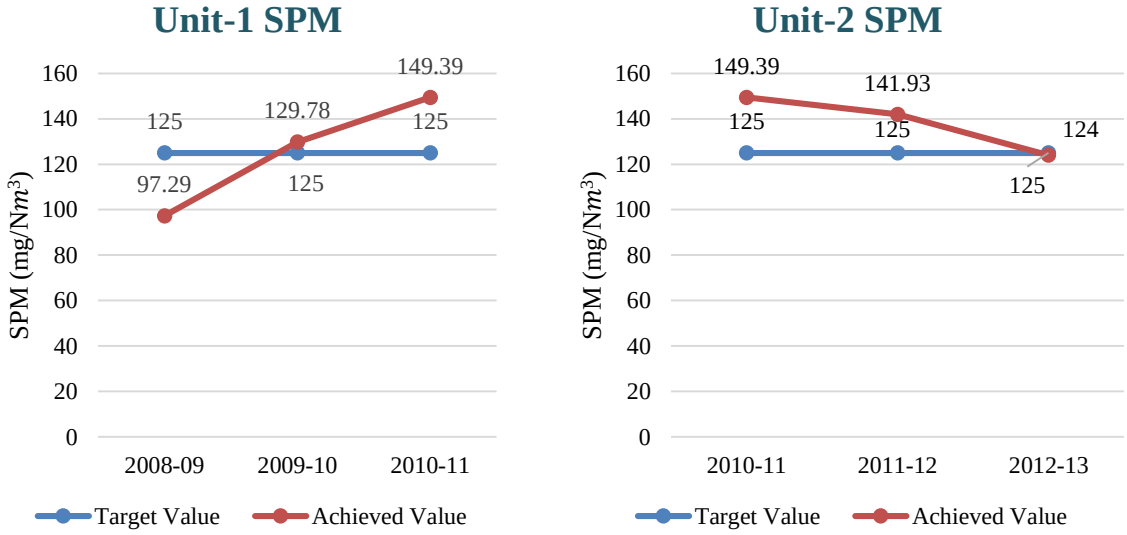

Fig. 4.10: Ukai Unit-1&2 SPM values (Target vs. Achieved) after R&M

The stack emission value measured as Suspended Particulate Matter (SPM) was less than the target value meaning it successfully complied with the environmental norms in the first year. For the second year it was very near to the target value which went up to 149.39 mg/Nm^3.

For unit-2 the SPM values were high in first year which went down in the following years ultimately achieving the target value in third year.

Thus there has been some increase in Gross generation and P.L.F of both Units 1 & 2 but reduction in APC and Specific Oil Consumption, Specific Coal Consumption and Heat Rate observed after R&M. Also full generation could not be achieved because the units did not attain full load i.e. 120MW.

Although performance of Ukai units-1 & 2 improved, but post R&M outputs achieved have not been in line with the envisaged targets. Further occurrence of technical surprises during execution of R&M works, like, replacement of generator stator bars due to flashover on unit-1 overhang stator winding coil, additional rewinding and re-caging of H.T. motors, resulted into unsatisfactory performance of units after R&M/LE works. Forced outages of both the units increased after R&M due to following problems faced in O&M activities after R&M.

a. TG bearing numbers 6H/6V and 7H/7V vibration remained high. Also, temperature of turbine bearing number 3was constantly high.
b. FD fan of unit 1 had no margin no operation i.e. it was running with full capacity.
c. Both NASH pumps were required to run to achieve full load for both the units.
d. Drum level could not be maintained by running one BFP at full load. For running the unit at full capacity it was required to run both the BFPs.
e. De Aerator level could not be maintained by running one CEP at full load, for that they needed to run both the pumps simultaneously.
f. PG test have not been conducted yet.

4.2.2 Amarkantak TPS (2x120 MW)

R&M of unit-1 was done from 01/11/2010 to 19/02/2012 i.e. it took 16 months to complete the activity**.** R&M of unit-2 was done from 01/06/2011 to 14/11/2011 i.e. it took 6 months to complete the R&M works**.** It is observed from the comparison of performance of the unit, before and after R&M works that:

i. Units # 1 & 2
   a) Gross Power Generation of unit#1 increased from 498.44 MU in 2008-09 to 602.01 MU in 2012-13 but could not reach full level.
   b) Gross Power Generation of unit#2 increased from 515.60 MU in 2008-09 to 657.43 MU in 2012-13
   c) PLF of both the units increased from 48.23% to 59.91% for the same period
   d) APC of both the units reduced from 12.53% to 9.46% for the same period
   e) Specific Oil Consumption of both the units decreased from 4.07 ml/kWh to 3.37 ml/kWh
   f) Specific Coal Consumption of both the units remained almost same
   g) Heat Rate of both the units increased from 3691 kCal/kWh to 3765 kCal/kWh for the same period
   h) Unit#1 SPM has decreased from 188.33 mg/m^3 in 2008-09 to 133.75 mg/m^3 in 2012-13 for the same period
   i) Unit#1 SO_x emission decreased from 443.33 mg/m^3 to 379.66 mg/m^3 for same duration
   j) Unit#1 NO_x emission decreased from 349.16 mg/m^3 in 2007-08 to 245.83 mg/m^3 for same duration
   k) Unit#2 SPM has decreased from 146.81 mg/m^3 in 2007-08 to 132.28 mg/m^3 in 2011-12 for the same period

l) Unit#2 SO_x emission increased from 354.36 mg/m^3 to 432 mg/m^3 for same duration
m) Unit#2 NO_x emission decreased from 239.09 mg/m^3 to 243.85 mg/m^3 for same duration

The main reasons for unsatisfactory performance of 2 x 120 MW Amarkantak units were:

i) There were frequent changes in the scope of work, due to funding constraints
ii) R&M for different equipment executed through different vendors
iii) R&M executed on piece meal basis over a long period of time

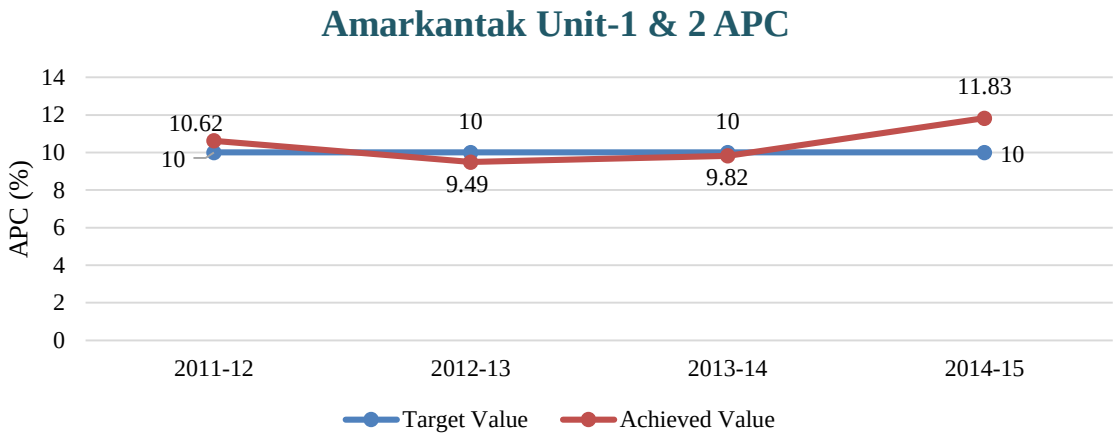

Fig 4.11: Amarkantak TPS APC values (Target vs. Achieved) after R&M for unit-1 & 2

The APC value of both the units were commonly provided, it was slightly high during first year, after that it achieved the target value for two consecutive years then again it went up to 11.83% for fourth year. Due to non-availability of forced outage data during Pre R&M period comparison cannot be made with the Post R&M values.

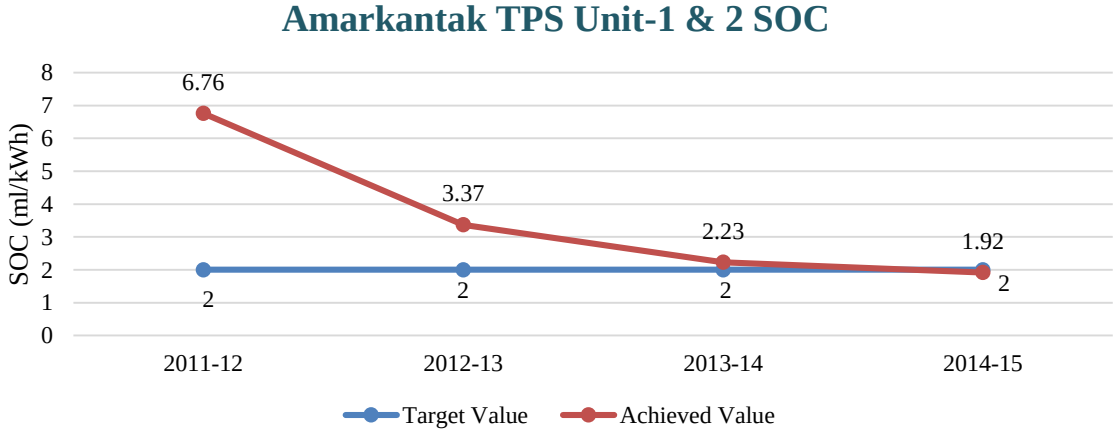

Fig 4.12: Amarkantak TPS SOC values (Target vs. Achieved) after R&M for unit-1 & 2

The Specific Oil Consumption (SOC) was very high during first year after R&M i.e. 6.76 ml/kWh which was improving consistently during the following years and finally it achieved the target value and the value was 1.92 ml/kWh.

4.2.3 Obra TPS (2x200 MW)

R&M of Unit # 9 was conducted from 02.11.2008 to 26.06.2011. Unit# 9 Synchronized on 26th June 2011 The scrutiny of tables and charts presented earlier, reveals that both Gross Generation and PLF increased after R&M. Further Heat Rate, Auxiliary Consumption and Oil Consumption reduced after R&M. Forced outages of unit-9 reduced after R&M works.

R&M of Unit # 10 was commenced from 22nd March, 2012 and the unit was synchronized on 31st March, 2016. The scrutiny of tables and charts presented earlier, reveals that both Gross Generation, and PLF were on the downward trend which necessitated the implementation of R&M works.

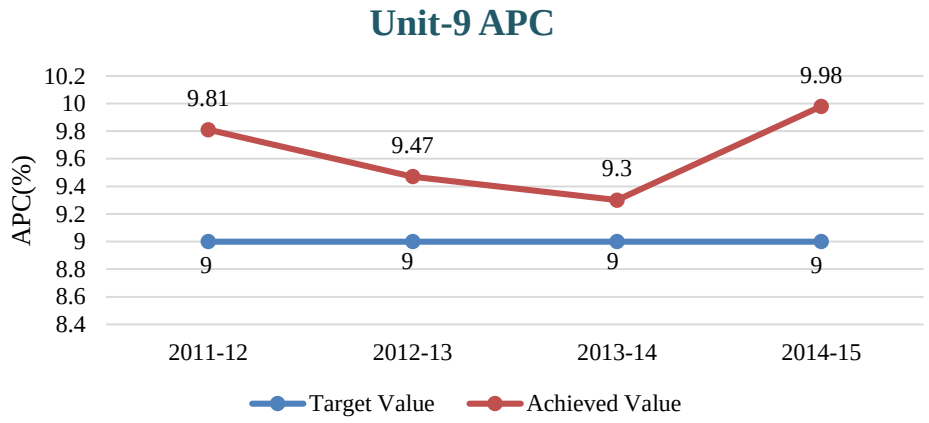

Fig. 4.13: Obra Unit-9 APC values (Target vs. Actual) after R&M

The auxiliary power consumption value of the unit was slightly high during first year after implementation of R&M works which was in the decreasing trend for the next two years and it came to 9.3% but it again rose during fourth year to 9.98%.

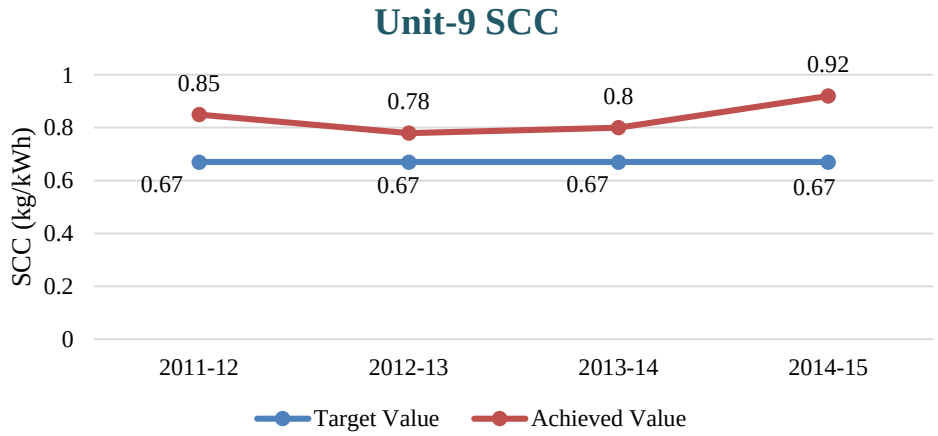

Fig. 4.14: Obra Unit-9 Specific Coal Consumption values (Target vs. Actual) after R&M

The Specific Coal Consumption (SCC) was higher than the target value for all the years. During first year it was high then it started decreasing during second year but it again started rising during third and fourth year and it went up to 0.92 kg/kWh.

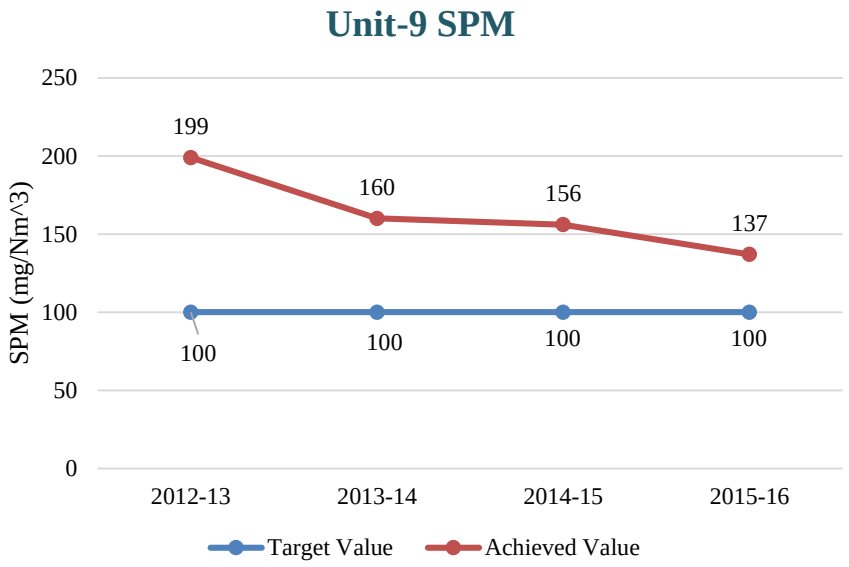

Fig. 4.15: Obra Unit-9 SPM values (Target vs. Actual) after R&M

The stack emission had done good as it was almost double during first year after performing R&M activities but it started declining during from second year and it was 137 mg/Nm^3 during fourth year.

It is observed from the comparison of performance of the unit, before and after R&M works that:

i) Unit # 9:
   a) Increase in Gross Generation
   b) Increase in P.L.F.
   c) Reduction in Auxiliary Power consumption
   d) Reduction in Specific Oil Consumption
   e) Reduction in Heat rate

ii) Unit # 10:
   The unit was synchronized on 31st March, 2016 and it again was shut down in July, 2016 due to some major boiler works and again synchronized on 01st December, 2016. It was run for a total for 4 months till end of December, 2016. It showed below performances:
   a) Reduction in APC
   b) Reduction & improvement in Heat Rate

4.2.4 GNDTP Bathinda TPS (2x110 MW), PANJAB

Unit-3 was taken under shutdown on14.01.2010, and synchronized on 05.8.2012 after L.E. works. Unit-4 was taken under shut down on 05.11.2012 and synchronized on 23.06.2014 and on coal on 10th July 2014. It is observed from the comparison of performance of the unit, before and after R&M works that:

i. Unit # 3
   a) No improvement in Gross Generation
   b) Slight Improvement in P.L.F.
   c) Reduction in Auxiliary Power consumption
   d) Reduction in Specific Oil Consumption
   e) Reduction in Specific Coal Consumption
   f) Reduction in Heat Rate

ii. Unit # 4
   i) No improvement in Gross Generation
   ii) Slight Improvement in P.L.F.
   iii) Reduction in Auxiliary Power consumption
   iv) Reduction in Specific Oil Consumption
   v) Reduction in Specific Coal Consumption

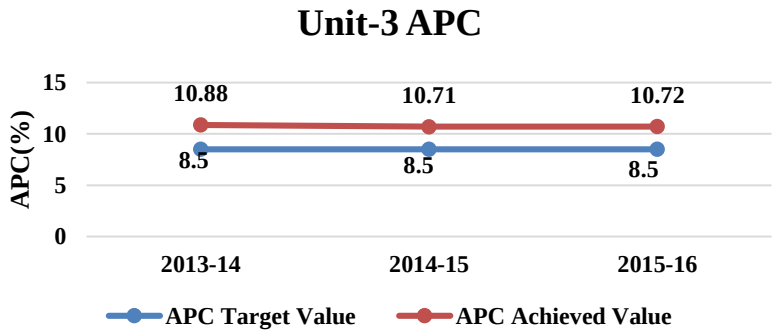

Fig. 4.16: GNDTP Unit-3 APC values (Target vs. Actual) after R&M

The APC value was found constantly higher than the target value.

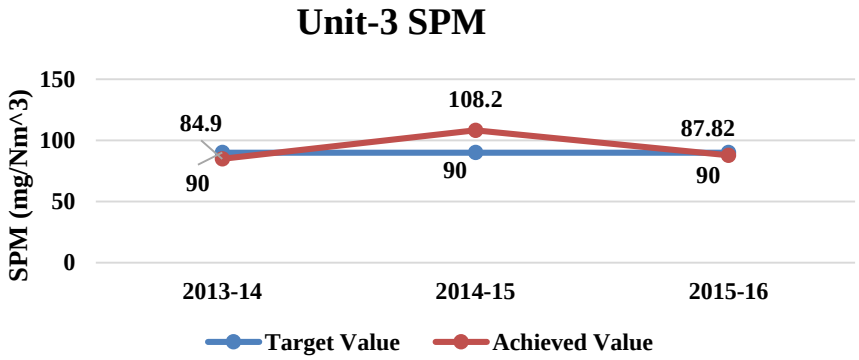

Fig. 4.17: GNDTP Unit-3 SPM values (Target vs. Actual) after R&M

The stack emission values achieved the target value during first year of operation but it increased during second year to 108.2 mg/Nm^3 and it again achieved the target value during third year after implementation of R&M works. Forced outages of unit-3 remained almost same of the Pre R&M values and that of unit-4 decreased after R&M works.

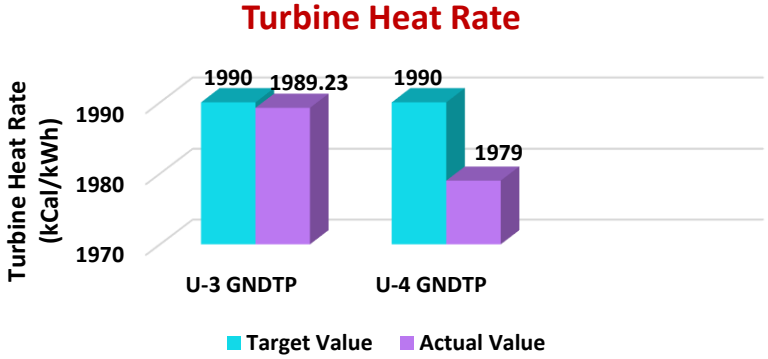

Fig. 4.18: Heat Rate values (Target vs. Actual) of GNDTP Unit-3&4 Turbine

Actual Turbine Heat Rate as per PG test of unit-3 was 1989.23 kCal/kWh and actual Turbine Heat Rate as per PG test of unit-4 was 1979 kCal/kWh against the targeted Heat Rate value of 1990 kCal/kWh for both the units. Average values of SPM level was from 32.7 to <100 mg/Nm^3 for unit-3 and it was from 24.2 to <100 mg/Nm^3 for unit-4 during PG tests. Average values of SO_2 level was from 315 to <550 mg/Nm^3 for unit-3 and it was from 56 to <450 mg/Nm^3 for unit-4 during PG tests. Average values of NO_x level was from 197 to <550 mg/Nm^3 for unit-3 and it was from 35 to <450 mg/Nm^3 for unit-4 during PG tests.

4.2.5 Unit 5 Bandel TPS (1x210MW)

The Gross Unit Heat Rate of unit-5 achieved was 2287 kCal/kWh at 220MW load and 2284 kCal/kWh at 217 MW load against the target value of 2345 kCal/kWh at 215MW load during PG test of the unit.

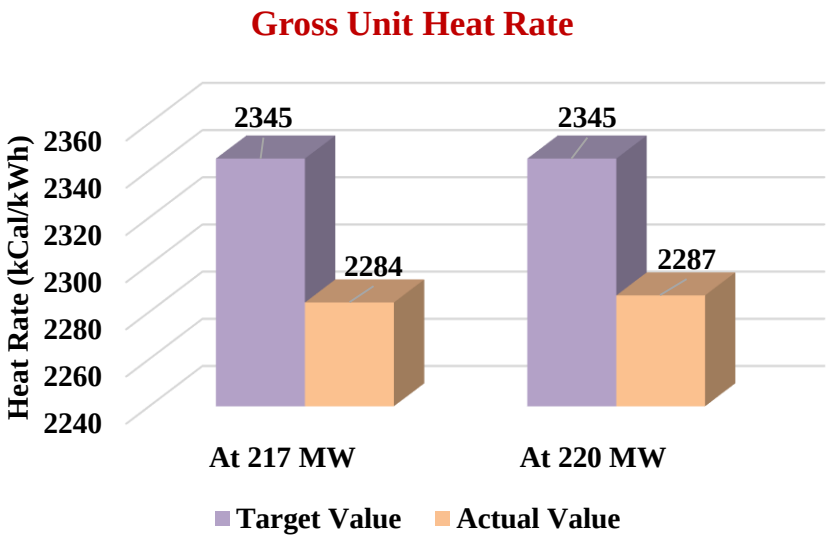

Fig. 4.19: Gross Unit Heat Rate values (Target vs. Actual) of Unit-5 of Bandel TPS

Similarly, the target value of Gross Power Output was fixed at 215MW. However, the unit achieved the value of 220MW during PG test. Target value of APC was fixed at 6.04% and it achieved 5.13% during PG test. Target value of SPM was fixed at 90 mg/Nm^3 and it achieved 79.20 mg/Nm^3 during PG test. Forced outages of unit-5 has decreased after R&M works.

4.2.6 Unit# 6 Koradi TPS (1x210 MW)

DPR approved by MSPGCL/MERC. Electrical Package awarded to M/s ABB. Contract for BOP Package signed on 10.8.2012.BTG Package: Contract agreement signed on18.12.2013 with M/s BHEL. The project is still under R&M implementation stage.

4.2.7 Unit# 1 Muzaffarpur Thermal Power Station (1x120 MW), BIHAR

Unit# 1 was under shut down on 06.10.2003 and Synchronized on 05.07.2013 after completion of R&M 05.07.2013. The scrutiny of charts and table presented earlier, reveals that both Gross Generation and PLF were on the increasing trend after R&M.

Thus, it can be summarized from perusal of charts and table presented earlier, that there was significant increase both in Gross Generation and PLF after implementation of R & M works. Further the improvement in other important parameters is also visible such as reduction in Heat Rate, Auxiliary Consumption, Oil Consumption and Coal Consumption, respectively.

4.3 Problems/Challenges faced in O&M

Problems/challenges faced by the Power Utilities along with suitable measures for further improvements are suggested below.

Table 4.8: Challenges Faced during O&M after R&M

S. No.	Equipment / Plant Section	Problems/Challenges faced	Suitable Measures for further Improvements
I	**Steam Generator and Auxiliaries**		
i.	Boiler Drum and DE aerator level	Levels cannot be maintained	Additional BFPs, CEs & NASH Pumps may have to be run depending upon actual requirements
II	**Turbo-Generator & Auxiliaries**		
	TG Bearing	Vibrations of TG Bearing	To be monitored and kept within limits
III	**Performance of Units**		
i.	Generation level Drum level De- Aerator	Generation level not achieved Drum level cannot be maintained DE aerator level cannot be maintained	Additional No of equipment may be run such as NASH Pumps, CEPs, and BFPs etc. to achieve the said Generation level. However a provision in the contract for shortfall in performance may be made.

In addition to the above, frequent tube leakages at GNDTP units, specifically from economizer banks were experienced. To solve this problem the plant authorities had done 100% radiography of economizer joints and defective joints were re-welded. Earlier, only 10% joints were checked by radiography, which were resulting into frequent shutdowns of the unit.

The problems and challenges faced in O&M after R&M at Ukai units were high TG bearing temperature, high vibration in Generator bearings. Since all the TG bearings were replaced, the reasons for vibration and increased temperature of the bearings could be due to non-fitment of bearings properly and/or grouting. Load could not be reached up to the uprated capacity of 120MW, so additional BFP, CEP pumps had to be run resulting in increased APC of the units.

The problems faced at Amarkantak TPS was high bearing temperature and high eccentricity of HP/IP turbine during rolling. It was due to ageing of units as per M/s. NASL.

The problems at unit-9 & 10 of Obra TPS was due to non-commissioning of certain equipments and also due to unavailability of certain vendors.

At GNDTP Bathinda units, mill reject increased and the problem resolved by increasing the size of air-port assembly. Malfunctioning of some pressure valves observed which was rectified by adjusting the spring tension of the valves. There was slow ash evacuation from ESP hoppers due to intermittent air flow which was changed to continuous flow and now the problem is resolved. Similarly, there were problems in other areas also but they were resolved by taking remedial measures.

At KBUNL, Muzaffarpur grinding elements failing frequently before their useful life, failure of Turbine gaskets and LP turbine were some of the problems arising in the unit.

At Barauni TPS there was some problem in DCS system, leakages in instrument air-line, lack of spares etc., which caused drop in power generation of the unit.

At Bandel TPS, the unit achieved 10MW more than its target peak load of 215MW, Heat Rate, SCC values are also very good for this unit.

Thus, it can be observed from above that after carrying out R&M works, normally there is some increase in the performance parameters such as Gross Generation & PLF and reduction/improvement in parameters such as APC, SOC, SCC & Heat Rate with the exception of some specific Thermal Power Stations.

Chapter-5

Learnings & Experiences

It is very important to evaluate whether the goals and objectives of the R&M project have been achieved. From the study and analysis of the detailed data/information gathered of the Ukai TPS, Ammarkantak TPS, Obra TPS, GNDTP Bathinda, KBUNL Muzaffarpur, Barauni TPS, Bandel TPS and Koradi TPS, it has been observed that the success of R&M projects of various plants had varied. The Post R&M performance of the unit had been quite encouraging and close to the expected results in the operation & maintenance of the units after implementation of R&M works are summarized below:

1. Whereas generally improvement has been experienced in most of the important performance parameters such as Gross Generation, PLF, APC, SOC, SCC and Heat Rate. But due to specific problems like excessive vibration and high temperature of turbine bearings, unit could not be run on full load. Similarly, in some cases, full load could not be achieved without running extra BFP and CEP resulting into increased auxiliary power consumption. In most of the cases, units took more time (upto 1 year) in stabilization and giving desired performance.

2. PG Tests are not usually conducted after commissioning of the units as a performance check after undergoing R&M. PG test has been conducted only at units- 3&4 of Bathinda TPS and unit-5 of Bandel TPS. These units achieved their targeted values after R&M in terms of MW and Turbine Heat Rate. In case of both units of Ukai TPS PG test could not be conducted as unit did not achieve rated capacity of 120MW. For Amarkantak TPS, PG test could not be conducted as R&M works were carried out by large number of firms/contractors and the same was not under their scope. Similarly, for Obra TPS PG test could not be conducted for both the units-9 & 10, as some works such as TG auto loops, SLDC, Burner tilt mechanism, cooling tower fans have not yet commissioned. Also, there is axial shift problems in both the units. For unit-1 of Muzaffarpur TPS, PG test has not yet been conducted since BHEL has not submitted revised turbine PG test/demonstration.

3. At Ukai TPS, it was observed in both the Units (Unit No#1&2) that the Boiler Drum and Deaerator level could not be maintained with required number of BFP and CEP respectively. It was seen that a maximum load of only 114MW could be achieved by running two BFPs & one CEP as per normal practice.

However, for achieving full rated load of 120MW, three BFPs were required to maintain Boiler Drum level and similarly two CEPs were run to maintain De-Aerator level. In such cases, necessary measures i.e. overhauling/replacement of pumps are required to improve the performance of BFP/CEP etc. Further, at Ukai TPS, it was observed that vibrations of TG Bearing No.6 & 7 of Unit # 1 remained high.

4. It is very essential to strictly follow the maintenance schedule after completion of R&M works, and to adhere to annual maintenance schedule strictly to avoid deterioration in condition of machines/ equipment. Hence, best practices in O&M should be followed after implementation of R&M of the units. In addition, proper training should be given to operation & maintenance engineers/staff for efficient operation of the unit post R&M.

5. At GNDTP, Bathinda, there were frequent joint leakages in Boiler area specifically in Economizer Banks. In order to reduce such frequent leakages, during R&M of Boiler 100% radiography of joints at site was done instead of present practice of 10%. This helped in improving the Generation of units and also reduction in oil consumption as frequent shut down of the units due to this problem reduced.

6. It has been observed that the units, where R&M of Electrostatic Precipitator has been done, are able to meet the new stricter norms of SPM level of 100 mg/Nm^3.

Appendix-I

Terms of Reference

1. Background

1.1 India currently has an installed generation 173,626 MW (as on 31.03.2011), of which 93918 MW (54 percent) is coal-fired contributing major share of total generation. While much of the 1970s (and older) vintage units have been or need to be retired, many of the coal-fired power plants (NTPC as well as state utility owned plants) that were commissioned in and before early 1980s are now due for rehabilitation and life extension.

1.2 CEA has prepared a National Perspective Plan for facilitating the R&M (Renovation & Modernization) and L.E. (Life Extension) works at various thermal power stations in the country. Through the Perspective Plan, efforts would be made to facilitate rehabilitation of the old thermal plants with an objective of efficiency enhancement, life extension, up-rating and reduction in Greenhouse Gases emissions by repair, replacement, modification and technology up gradation. Fifty three (53) units with a total capacity of 7318 MW of Life Extension (LE) works & seventy six (76) units with a total capacity of 18965 MW for R&M works have been identified for the 11th Plan. Similarly for the 12th Plan, LE works on seventy two (72) thermal units of total capacity 16532 MW and R&M works on twenty three (23) units of total capacity 4971 MW have been identified under the above National Perspective Plan.

1.3 The World Bank has financed the "Coal-Fired Generation Rehabilitation Project" for demonstrating energy efficient rehabilitation and modernization (EE R&M) of coal fired generation units through rehabilitation of 640 MW of capacity across three states- West Bengal, Haryana and Maharashtra. The project would also address critical barriers to large scale EE R&M in India. The project would be funded through IBRD loan of US$ 180 million and GEF grants of US$ 45.4 million. The project has two components:-

Component-1: Energy Efficiency R&M Pilots Using US $ 180 million of IBRD loan and US $ 37.9 million of GEF grants:

This component would fund Energy Efficient R&M of 640 MW capacity comprising Bandel TPS Unit-5(210 MW) of WBPDCL, Koradi TPS Unit-6(210 MW) of Mahagenco and Panipat TPS Unit-3&4 (2x110 MW) of HPGCL. The World Bank has earmarked US$ 180 million of IBRD loan and US $ 37.9 million of GEF grants for the Component-1.

Component-2: Technical Assistance to address Critical Barriers to EE R&M:

The World Bank has earmarked US $ 7.5 million GEF Grant for the Component-2. The sub-components for the technical assistance program would cover:

i. Support for design of Energy Efficient R&M projects.
ii. Support for implementation of demonstration of EE R&M investments funded under Component-1 of the project.
iii. Support for addressing barriers to EE R&M projects.
iv. Support for strengthening of institutional capacities of utilities.

1.4 Under the sub-component (iii) of the component-2 (Technical Assistance) around US$ 1.1 million of GEF Grants are being made available to provide technical support to CEA aimed at addressing barriers to implementation of R&M in India. This component would be implemented through the Central Electricity Authority through appointments of Consultants including Implementation Support Consultant (ISC) to carry out following studies –

i) Review of Institutional Capacity and Implementation of Capacity Strengthening Interventions at CEA
ii) Reduction of barriers to R&M interventions in thermal power plants in India;
iii) Developing markets for implementation of R&M scheme in thermal power stations in India;
iv) Review of experience from Pilot R&M interventions in thermal power stations in India.

1.5 Ministry of Power, GOI vide letter No. 10/1/2009-IC dated 07.01.2009 have conveyed in-principle approval for the above proposed project under the title "National Programme for R&M". CEA has been identified as the Project Implementing Agency for sub-component (iii) of Component -2 for Technical Assistance. The sub-component (iii) would be implemented under the title **"Technical Assistance to CEA for Addressing the Barriers to Energy Efficiency R&M of Coal Fired Generating Units in India"**.

1.6 CEA has already appointed Implementation Support Consultant who is assisting CEA in appointing the Consultants for the above four studies and in co-ordination amongst CEA & various Consultants and monitoring of Consultant's works & Pilot R&M projects funded by World Bank.

1.7 The World Bank is supporting pilot energy efficiency focused R&M interventions at Unit-5 of Bandel TPS, Unit-6 of Koradi TPS (Maharashtra State Power Generation Company Limited) and Units 3 & 4 of Panipat TPS. In addition, similar pilots are also being taken up under KfW funding at Nasik TPS (Maharashtra), Bokaro 'B' TPS (Damodar Valley Corporation) and Kolaghat TPS (West Bengal) under Energy Efficiency R&M Programmee under Indo-German Energy Forum. The National Electricity Policy envisages that Renovation & Modernization (R&M) for achieving higher efficiency levels needs to be pursued vigorously and all existing generation capacity should be brought to minimum acceptable standard. Hence, the Pilot energy efficiency focused R&M projects have been facilitated to gain an experience from these Pilot R&M projects and to implement the same at other thermal power stations in India.

2. Assignment & Broad Scope of Work

The main objective of the assignment is to procure Consultant who inter-alia would review the experience of the activities which have been carried out in the Pilot R&M Projects during different stages of preparation and implementation of these projects and would prepare reports for dissemination of the experience across Utilities in India. The consultant will also review the implementation experience at other R&M projects taken up by the utilities during 11th Plan and 12th Plan.

The main task of the Consultant would be to facilitate CEA in sharing of experience on Pilot R&M projects and other R&M/LE projects taken up during 11th plan and 12th plan.

For this, CEA would require support from the Consultants in the following manner but not limited to:

a) Review of Procurement Experience including preparation of DPR, Bidding documents, etc.;
b) Review of R&M Implementation Experience;
c) Review of Experience in Strengthening of O&M Practices;
d) Review of Post-R&M Experience in O&M;
e) Dissemination of Learnings from Pilot R&M Interventions.

3. Detailed Description of Tasks

Work would be undertaken in the manner as given below:

3.1 Review of Procurement Experience for Pilot R&M Projects

a) The Consultant shall analyse and review the procurement experience in awarding R&M works for Pilot R&M projects funded by the World Bank and KfW. The Consultant shall, especially, look into the DPR, Bidding documents, Qualification Requirements, Performance Guarantees and Project Schedule. The Consultant shall also review the Evaluation Criteria including Project Schedule and Performance Parameters and the impact of these on the overall level of competition and price bid discovery. For review of the procurement experience, the Consultant shall cover all the R&M related procurement activities completed till May 2014 at the identified thermal power stations as part of study.

b) The Consultant shall carry out analysis of bidding process followed by the power generating companies in selection and procurement of consultants/suppliers to undertake the required R&M interventions. The Consultant shall also analyse and review the key steps undertaken to ensure competitiveness in the bidding process and suggest the possible options to improve the competitiveness in the bidding process.

c) The Consultant shall examine the various other factors that may have affected the procurement outcome at the Pilot R&M Projects of World Bank and KFW; and also analyse the problems faced while finalizing the contract(s) for Pilot R&M Projects.

d) The Consultant is required to visit the selected thermal power stations to collect and compile the relevant information and document to undertake the desired review and analysis.

e) The Consultant shall prepare and submit a report on learnings from the procurement experience from the Pilot R&M Projects of the World Bank and KfW projects for dissemination purposes for future R&M projects.

f) The review exercise will be limited to the thermal power stations as mentioned in the **attached list of projects as Annexure I.**

3.2 Review of R&M Implementation Experience

a) The Consultant shall review the available R&M Implementation Experience at thermal units in various thermal power stations as **mentioned in Annexure-II.** .

Broadly, the review would include inter-alia the time and cost aspects, technical surprises, contractual arrangements and the performance achieved. The Consultant shall cover R&M Implementation Experience available at the above mentioned thermal power stations till two months before the scheduled timeline for submission of Draft Final Report on this activity.

b) The review of the R&M Implementation experience shall also include the analysis of project management process and identify the areas where the actual project implementation deviated from desired objectives and analyse the reasons for such deviations.

c) The Consultant is required to visit the selected thermal power stations to collect and compile the relevant information & documents to undertake the desired review and analysis.

d) Based on the review of R&M implementation experience, the Consultant shall prepare a report on R&M/LE Implementation Experience which may be helpful to the generating companies for carrying out the R&M works in future.

3.3 Review of Experience in Strengthening O&M Practices

a) The Consultant shall review the interventions of Operations & Maintenance (O&M) strengthening practices undertaken by the concerned power generating companies – WBPDCL, MSPGCL and HPGCL.

b) The Consultant shall review the strengthening interventions undertaken by the utilities for enhancing O&M practices across the various facets including technology, O&M planning, conditional monitoring, preventive maintenance, O&M procedures, enhancement in technical & managerial skills of O&M personnel and infrastructure/facilities improvement etc.

c) The Consultant shall indicate the benefits accrued on account of the various strengthening interventions in O&M practices undertaken at these thermal power stations.

d) The Consultant shall list out the drawbacks/shortcomings faced in the O&M practices followed by power generating companies after implementation of the strengthening interventions and suggest possible measures for further improvements.

e) The Consultant may be required to undertake visits of above mentioned power generating companies for the purpose of the review of the experience in strengthening O&M practices.

f) Based on the review and discussion with the generation utilities, the Consultant shall prepare a report on strengthening of Operation & Maintenance (O&M) practices followed by these power generating companies for the purpose of sharing the learnings/experience.

3.4 Review of Post - R&M Experience in O&M

a) The Consultant shall review and share the Post - R&M Experience in O&M after the plant has been in operation for a considerable time (say about six months) after completion of R&M works at the thermal power stations as **mentioned in Annexure III**. The review will include Post -R&M review of the operational performance of the generating units where R&M interventions have been undertaken **till eight months before the scheduled timeline for submission of Draft Final Report** and indicate the improvements in their operational performance.

b) The Consultant shall list out the problems/challenges faced in O&M of thermal unit after implementation of the R&M interventions and suggest suitable measures for further improvements in the units.

c) The Consultant may be required to make visits to listed thermal power stations for the purpose of review of the Post- R&M experience in O&M.

d) Based on the review of O&M experience, the Consultant shall prepare a report on Post R&M experience in O&M at the listed thermal power stations for the purpose of sharing the experience for future R&M units.

3.5 Dissemination of Learning from Pilot R&M Interventions and other R&M Projects

a) The Consultant in association with CEA will conduct One (01) workshop in Delhi for sharing of experience with different stakeholders on R&M activities carried out at Pilot R&M projects and other R&M Projects.

b) The Consultant shall submit Fifty (50) copies and soft copies in CD's of all Final Reports to CEA for sharing experience with the future R&M projects.

4. Deliverables and Tentative Time Schedule for completion of task

4.1. The contents and break-up of the deliverables/reports will have to be agreed with CEA. The assignment is likely to commence in May 2012 and the tentative time schedule for completing the various activities is as under:

S.No	Deliverable	Timeline (Tentative)
1.	Inception Report	June 2012
2.	Draft Report on review of procurement experience (available till the timeline) at Pilot R&M Projects	December 2012
3.	Draft Report on review of Experience (available till the timeline) in Strengthening O&M practices	July 2013
4.	Draft Report on review of R&M Implementation experience (available till the timeline) at Pilot R&M Projects and other R&M projects	December 2013

5.	Draft Report on review of Post - R&M experience in O&M of the thermal power stations	April 2014
6.	Draft Final Report on review of procurement experience available at Pilot R&M Projects [1]	June 2014
7.	Draft Final Report on review of Experience in Strengthening O&M practices[2]	June 2014
8.	Draft Final Report on review of R&M Implementation experience available at Pilot R&M Projects [3]	July 2014
9.	Draft Final Report on review of Post - R&M experience in O&M of listed thermal power stations[4]	July 2014
10.	Conduct Workshop for sharing of experience on Pilot R&M Projects with Stakeholders	September 2014
11.	Final Report on review of procurement experience available at Pilot R&M Projects	October 2014
12.	Final Report on review of Experience in Strengthening O&M practices	October 2014
13.	Final Report on review of R&M Implementation experience available at Pilot R&M Projects	October 2014
14.	Final Report on review of Post R&M experience in O&M of the listed thermal power stations	October 2014

Note:

1 The Draft Report shall include the experience in procurement available at the R&M projects till the indicated timeline. The rest of the experience in procurement at the R&M projects available during the period between submission of the Draft Report and Draft Final Report shall be included in the Draft Final report.

2 The Draft report shall include the experience in strengthening O&M practices available at the R&M projects till the indicated timeline. The rest of the experience in strengthening O&M practices at the R&M projects available during the period between submission of the Draft Report and Draft Final Report shall be included in the Draft Final Report.

3. The Draft report shall include the experience in implementation available at the R&M projects till the indicated timeline. The rest of the experience in implementation at these R&M projects available during the period between submission of the Draft Report and Draft Final Report shall be included in the Draft Final Report.

4 The Draft report shall include the Post- R&M experience in O&M till the indicated timeline. The rest of the experience in the Post- R&M experience in O&M available during the period between submission of the Draft Report and Draft Final Report shall be included in the Draft Final Report.

4.2. The Consultant will be required to submit monthly and quarterly progress reports to CEA.

4.3. The Consultant shall submit 10 copies of Inception Report, 10 copies of all Draft Report, 10 copies of all Draft Final Report and 50 copies of all Final Reports.

4.4. All deliverables/reports shall be prepared in hard form and also in electronic form (Word, Excel, Power Point, pdf files etc.). The reports shall be submitted on A4 Size paper with adequate size of alphabets/symbol & line spacing.

5. Support/Inputs to be provided by CEA

5.1. CEA will be the Employer of the Consultant and will nominate a Project Manager. Project Manager will act as liaison officer to the Consultant's team. He will be the point of contact and initial addressee for all aspects of the works.

5.2. The CEA will provide all existing information, data, reports and maps as available and will assist the Consultant in obtaining relevant information and materials from government institutions and state authorities to the extent possible.

5.3. CEA will not provide any space for office.

5.4. Personal Computers, Laptops, printers, photocopier, stationery items etc. will be arranged by the consultant.

6. Consultant Skill Sets and Team Composition

The Consultant team should have an appropriate mix of experience and expertise in India and abroad in respect of Renovation & Modernisation of thermal power plants and Power Sector Policy /Regulations. The Key Professional Staff in the Consultant team are expected to be from technical background and also having the knowledge of Indian Power Sector, especially with regard to Operation & Maintenance of thermal power stations and R&M/LE programme implementation. The team of the Consultant shall comprise a Team Leader, one R&M Expert, one O&M Expert, one Commercial Expert & one Environment Expert. The Key Professionals would be spending their time depending on requirement of the assignment during the entire duration of the assignment. The Consultant should have an in depth knowledge of the current R&M/LE guidelines/policies and regulatory frameworks for thermal power plants in India. The Consultant should also have expertise in assessing environmental impact/benefits of the R&M/LE projects. The Consultant may propose additional members in their team to provide required expert services in other areas / tasks identified by them. The required qualification & experience is given in the table below:

S. No.	Key Position	Minimum Qualification and Experience	
1.	Team Leader	B.E. / B. Tech	Team Leader shall have minimum fifteen years (15 years) professional experience in Power Sector including ten years' experience in O&M / R&M of coal fired thermal power stations having units of capacity of 110 MW and above.
2.	R&M Expert	B.E. / B. Tech.	R&M specialist should have minimum ten years (10 years) experience in Power sector including two years' experience in R&M of coal fired thermal power stations having units of capacity of 110 MW and above.
3.	O&M Expert	B.E. / B. Tech.	O&M specialist should have minimum ten years (10) years' experience in Power sector including five years' experience in O&M/ R&M of coal fired thermal power stations having units of capacity of 110 MW and above.
4.	Commercial Expert	MBA/B.E. / B. Tech.	Commercial expert should having minimum ten years (10 years) experience in contract management in Infrastructure sector including three years (3 years) experience on contract management in R&M/O&M of coal fired thermal power stations.
5.	Environment Expert	Graduation / Post Graduation Degree in Environment.	Environment Expert should have minimum ten years (10 years) experience in assessing the environmental aspects of infrastructure projects.

ANNEXURE-I

List of Units to be considered for review of Procurement Experience for Pilot R&M projects

Sl No	Unit No	Capacity (MW)	Name of Thermal Power Station (TPS)	Name of Utility/State	Executing Agency	Completion of LE Works/Status
1	6	1X210	Koradi TPS	MSPGCL/Maharashtra	Yet to be awarded	DPRs are under finalisation
2	5	1 x 210	Bandel TPS	WBPDCL/West Bengal	Yet to be awarded	DPRs are under finalisation
3	1, 3 & 4	2x110, 1x110	Panipat	HPGCL/ Haryana	BHEL, Yet to be decided	DPRs are under finalisation
4	4 & 5	2x210	*Badarpur	NTPC	Yet to be awarded	DPRs are under finalisation
5	6,7&8	3x110	*Kothagudem	APGENCO, Andhra Pradesh	Yet to be awarded	DPRs are under finalisation
6	3	1x210	Nasik TPS	MSPGCL/Maharashtra	Yet to be awarded	DPRs are under finalisation
7	1 & 2	2x120	*Amarkantak	MPPGCL	Yet to be awarded	DPRs are under finalisation

* As per the meeting held at CEA on November 08, 2012 and Minutes of Meeting communicated by CEA vide their letter no. 2/52/TRM/CEA/2012/1888 dated 21.11.2012, Chandrapur TPS Units 1&2(1x210MW), Parli TPS Units 2&3 (1x 210 MW) and Kolaghat TPS Unit 3 (1x 210MW) have been replaced by Badarpur TPS Units 4&5 (2x210MW), Kothagudem TPS Units 6,7 and 8 (3x110MW) and Amarkantak TPS Units 1,2 (2x120 MW) respectively for Review of Procurement Experience for Pilot R&M projects (completed till May 2014).

ANNEXURE-II

List of Units to be considered for review of R&M Implementation Experience

Sl No	Unit No	Capacity (MW)	Name of Thermal Power Station (TPS)	Name of Utility/State	Executing Agency	Completion of LE Works/Status
1	1& 2	2x120	Ukai TPS	GSECL/Gujarat	BHEL	**Unit 1**- Unit was synchronized on 24 May 2008 after LE works **Unit 2** – Unit was synchronized on 24 February 2010 after LE works
2	9 & 10	1 X210	Obra	UPRUVNL/ Uttar Pradesh	BHEL	**Unit 9**- Synchronized in September 2010. Unit is under stabilization after R&M **Unit 10** –Shut down is expected in October 2011. LE works to be completed in 2012-13
3	3 & 4	2 x 110	Bhatinda TPS	PSPCL/Punjab	Unit 3 - BHEL,	**Unit 3**- Unit is expected to be Synchronized by November 2011 **Unit 4**- LE works to be taken after stabilization of Unit-3
4	1	1x110	Muzaffurpur	KBUNL/Bihar	BHEL	Expected date of Completion November 2011 after LE works
5	5	1 x 210	Bandel TPS	WBPDCL/West Bengal	Yet to be awarded	DPRs are under finalisation
6	1	1X210	**Talcher TPS	Odisha	Yet to be awarded	DPRs are under finalisation
7	1, 3 & 4	2x110, 1x110	Panipat	HPGCL/ Haryana	Unit 1- BHEL, Unit 3&4- Yet to be awarded	**Unit 1**- Unit was synchronized on 4 November 2008 after LE works **Unit 3** – DPRs for LE works is under finalisation **Unit 4** – DPRs for LE works is under finalisation

** As per the meeting held at CEA on November 08, 2012 and Minutes of Meeting communicated by CEA vide their letter no. 2/52/TRM/CEA/2012/1888 dated 21.11.2012, Koradi TPS Unit 6 (1x 210 MW) has been replaced by Talcher TPS Unit 1 (1x 210 MW) for review of R&M Implementation Experience.

ANNEXURE-III

List of Units to be considered for Review of Post-R&M Experience in O&M

Sl No	Unit No	Capacity (MW)	Name of Thermal Power Station (TPS)	Name of Utility/State	Executing Agency	Completion of LE Works/Status
1	1& 2	2x120	Ukai TPS	GSECL/Gujarat	BHEL	**Unit 1**- Unit was synchronized on 24 May 2008 after LE works **Unit 2** – Unit was synchronized on 24 February 2010 after LE works
2	1 & 2	2x120	Amarkantak Exten TPS	MPPGCL/Madhya Pradesh	BHEL	**Unit 1**- Expected date of Completion by October 2011 **Unit 2** – Unit was synchronized on 26 October 2010
3	9 & 10	1 X210	Obra	UPRUVNL/ Uttar Pradesh	BHEL	**Unit 9**- Synchronized in September 2010. Unit is under stabilization after R&M **Unit 10** –Shut down is expected in October 2011. LE works to be completed in 2012-13
4	3 & 4	2 x 110	Bhatinda TPS	PSPCL/Punjab	Unit 3 -BHEL,	**Unit 3**- Unit is expected to be Synchronized by November 2011 **Unit 4**- LE works to be taken after stabilization of Unit-3
5	1	1x110	Muzaffarpur	KBUNL/Bihar	BHEL	Expected date of Completion is November 2011 after LE works
6	7	1x110	Barauni TPS	BESB/Bihar	BHEL	Completion of LE works is expected in 2012-13
7	5	1 x 210	Bandel TPS	WBPDCL/West Bengal	Yet to be awarded	DPRs are under finalization
8	6	1X210	Koradi TPS	MSPGCL/Maharashtra	Yet to be awarded	DPRs are under finalization

APPENDIX-II

Fax: 011-2618 6904

Government of India
Central Electricity Authority
Thermal Renovation & Modernisation Division
Sewa Bhawan, 9th Floor, North Wing
R. K. Puram, New Delhi -11 00 66

No. 2/52/TRM/CEA/2012/ 1888

Dated: 21.11.2012

Subject: Minutes of the meeting held at CEA on November 08, 2012 to discuss the progress of various consultancy assignments awarded under the Project "Technical Assistance to CEA for Addressing the Barriers to Energy Efficient R&M of Coal Fired Generating Units in India" funded by World Bank. reg.

Enclosed please find herewith the Minutes of the Meeting held at CEA on November 08, 2012 to discuss the progress of various consultancy assignments awarded under the Project "Technical Assistance to CEA for Addressing the Barriers to Energy Efficient R&M of Coal Fired Generating Units in India" funded by World Bank.

(T.P Singh)
Chief Engineer (TRM) Div.

To

S/Shri

- C. Subramaniam, Senior Power Engineer, South Asia Sustainable Development-Energy, The World Bank, Hindustan Times House, 18-20, Kasturba Gandhi Marg, New Delhi-110001, Fax NO. 49247639
- Mr. Suresh Gehani, Director, ABPS Infrastructure Advisory Pvt. Ltd., 309, A-Wing, Kohinnor City, Kirol Road, OFF LBS Marg, Kurla (West), Mumbai - 400 070. (Fax-022 - 61240499)

- Mr. Vivek Srivastava, Technical Director, KPMG Advisory Services Pvt. Ltd., Building No 10, 8th Floor, Tower-B, DLF Cyber City, Phase-II, Gurgaon – 122002(India). (Fax: 0124-2549101)
- Mr. Anish De, Chief Executive Officer, AF - MERCADOS EMI, 1202, Millennium Plaza, Tower B, Sector - 27, Gurgaon(Haryana) – 122 002. (Fax : 0124-424-1751)
- Ms. M. Vanisree, Dy. Chief Engineer (Elect-I), WAPCOS Limited, 76-C, Sector - 18,Gurgaon (India), Pincode –122 015. (Fax: 0124-2349449)

Copy for information to :

1. SA to Chairman, CEA
2. SA to Member (Thermal), CEA
3. SA to Member (E&C),CEA

Minutes of the Review meeting held at CEA on November 08, 2012 to discuss the progress of various consultancy assignments awarded under the Project "Technical Assistance to CEA for Addressing the Barriers to Energy Efficient R&M of Coal Fired Generating Units in India" funded by World Bank.

A meeting was held on November 08, 2012 at CEA to discuss the progress of various consultancy assignments awarded under the Project "Technical Assistance to CEA for addressing the barriers to Energy Efficient R&M of Coal Fired Generating Units in India" funded by World Bank.

At the outset, Chief Engineer (TRM), CEA, Shri T.P Singh welcomed the representatives of World Bank and representatives from Consultancy Organisations.

Present:

The following representatives attended the meeting:

CEA:

- Sh. T.P Singh Chief Engineer (TRM) Div.
- Sh. Bhai Lal, Director, (E and R&M) Div.
- Sh. J. N. Prasad, Dy. Director, TRM Div.
- Sh. Anis Ahmad, Dy. Director, TRM Div.

World Bank:

- Sh. B. John Hamso, Senior Energy Economist
- Sh. C. Subramaniam, Senior Power Engineer
- Smt. Mani Khurana, Energy Economist

ISC (ABPS Infra):

- Sh. Suresh Gehani, Director
- Sh. Himanshu Agarwal, Deputy Manager

Mercados Energy Markets (India) Pvt. Ltd

- Sh. Anish De, Chief Executive Officer
- Sh. Vikas Gaba, Senior Manager
- Sh. Saurabh Gupta, Senior Consultant
- Sh. Rajarishi Goswami, Consultant

KPMG Advisory Services Pvt. Ltd. :

- Sh. Ashutosh Kumar, Manager
- Sh. Gaurav Goyal, Consultant

WAPCOS

- Smt. M. Vanisree, Addl. Chief Engineer, Power
- Sh. N.S Chauhan, Consultant

The summary of the discussions held during the meeting are as follows:

1. **Progress Review of Study on "Review of Institutional Capacity and Implementation of Capacity Strengthening Interventions at CEA"**

a. The representatives of M/s KPMG Advisory Services Pvt. Ltd. briefed about the status of Study on "Review of Institutional Capacity and Implementation of Capacity Strengthening Interventions at CEA" and submitted that Focussed Group Discussions with the Wing Nodal Officers and Special Assistants to the Members of 29 divisions of CEA have been undertaken as required for submission of report on Assessment of Institutional Capacity of CEA. Further, the Draft Questionnaire for undertaking the customer expectation surveys has been prepared and circulated to the Wing Nodal Officers and Special Assistants to the Members for comments. In this regard, World Bank representatives suggested KPMG to circulate Questionnaire to World Bank once it is finalised after incorporating the comments on the questionnaire.

b. M/s KPMG also discussed the list of stakeholders for undertaking customer expectation survey. With regard to the list of stakeholders, World Bank suggested to include SJVNL (Satluj Jal Vidyut Nigam Limited), Torrent Power and CESC (Calcutta Electric Supply Corporation) as a backup, in case consent for survey from any of the listed stakeholders is not obtained.

c. World Bank representatives further suggested that the CEA shall provide the letter addressed to Ministry of Power, Planning Commission, Ministry of Coal, Ministry of Environment & Forest etc. either of Member/Chairman of CEA to M/s KPMG Advisory Services Pvt. Ltd. to obtain the good response from customers.

2. **Progress Review of Study on "Reduction of barriers to R&M interventions in thermal power plants in India"**

a. The representatives of M/s Mercados Energy Markets (India) Pvt. Ltd. briefed about the status of Study on "Reduction of barriers to R&M interventions in thermal power plants in India" and submitted that the following Draft guidelines have already been submitted to CEA:

- Draft Guidelines for Risk Identification and Mitigation in R&M Projects
- Draft Guidelines for Early Identification of Potential Technical Surprises in R&M Projects and ways of addressing them.

b. M/s Mercados submitted that the next deliverable of "Draft Report on study for identifying the potential reduction in Green House Gas (GHG) emissions on account of R&M and suggesting possible framework for monetizing the GHG reduction" will be submitted during the week starting November 19, 2012.

c. M/s Mercados further requested CEA to extend the date of submission of "Draft Report on study of International best practices in R&M projects" as they are planning to visit some of the R&M projects implemented in other countries to obtain the first-hand international experience of Pilot R&M projects. M/s Mercados suggested to submit the Draft report on the same by first week of January. World Bank and CEA both agreed for the request and suggested M/s Mercados to submit report by first week of January.

d. World Bank suggested that the Draft Guidelines prepared by M/s Mercados should be sent to major Suppliers/Consultants/Utilities/Funding Agencies, which are playing vital role in R&M of thermal power stations for their comments, before these are discussed in the Task Force Meeting.

3. **Progress Review of "Study for Developing Markets for Implementation of R&M scheme in thermal power stations in India"**

a. The representatives of M/s Mercados Energy Markets (India) Pvt. Ltd. briefed about the status of "Study for Developing Markets for Implementation of R&M scheme in thermal power stations in India" and submitted that the Draft Excel based model for estimating the R&M Potential Assessment of coal based thermal power stations in India is almost prepared. M/s Mercados further informed that their team would like to have a discussion with CEA on the Model during the week starting November 19,

2012. Accordingly, based on discussions the Draft Report for the **"Study with the aim of developing markets to meet the impending demand of R&M in India"** will be submitted to CEA.

b. M/s Mercados further informed that they are planning to have Workshops/Road Shows on the draft report during the month of January 2013. Thereafter, the final Report for **"Study with the aim of developing markets to meet the impending demand of R&M in India"** will be submitted to CEA.

4. **Progress Review of Study on "Review of Experience from Pilot R&M Interventions in Thermal Power Stations in India"**

a. M/s WAPCOS Ltd. briefed that the revised Inception Report has been submitted to CEA and it will be finalised after incorporating CEA's comments on the same. Further M/s WAPCOS informed that site visit to Panipat Thermal Power Plant has been conducted.

b. During the meeting, the list of Plants selected for reviewing the various experience of R&M was discussed and it was decided to make the following replacements in the list of Power Plants selected for review of the "Procurement Experience for Pilot R&M Projects (completed till May 2014)" and "R&M Implementation Experience" considering the fact that desired experience may not be available at the power plant during the course of the study.

Table: List of the Power Plants to be replaced

S.No.	Existing Power Plants in the List	Replaced New Power Plants in the list
Procurement Experience for Pilot R&M Projects (completed till May 2014)		
1.	Chandrapur TPS, Units 1&2 (1x210 MW), Maharashtra	Badarpur TPS, Units 4 & 5 (2 x 210 MW), NTPC
2.	Parli TPS, Units 2&3 (1x210 MW) Maharashtra	Kothagudem TPS, Units 6, 7 & 8 (3 x 110 MW), APGENCO
3.	Kolaghat TPS, Unit 3 (1x210 MW), West Bengal	Amarkantak TPS, Units 1,2 (2 x 120 MW), MPPGCL
R&M Implementation Experience		
1.	Koradi TPS, Unit 6 (1X210 MW) Maharashtra	Talcher TPS, Units 1 (1x210 MW)

5. Task Force Meeting

It was discussed to schedule the next meeting of Task Force for Promoting Renovation & Modernisation(R&M) of Thermal Power Stations in India to December 17, 2012. Further it was discussed that during the next Task Force meeting, major Utilities/Suppliers/Consultants those are active in the field of R&M of thermal power stations, should also be invited to discuss the Guidelines prepared under the study Reduction of Barriers, i.e., "Draft Report and Guidelines for Risk Identification and Mitigation in R&M Projects" and "Draft Guidelines for Early Identification of Potential Technical Surprises in R&M Projects and ways of addressing them".

6. Hosting on Draft Guidelines on CEA Website

It was discussed that CEA may host "Draft Guidelines for Risk Identification and Mitigation in R&M Projects" and "Draft Guidelines for Early Identification of Potential Technical Surprises in R&M Projects and ways of addressing them" on its website for obtaining the comments of various stakeholders.

The meeting ended with a vote of thanks to the Chair.

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Appendix-III

Questionnaire

Format for Additional Data / Information required for Post R&M Experience in O&M

Name of the Plant:

Unit No & Capacity:

1. Background of the R&M Project.
2. Scope of R&M Project.
3. R&M works carried out.
4. Post R&M Experience in O&M after the plant has been in operation for a considerable time [about 6 Months or more] after completion of R&M Works

[Period of R&M Works: From--- to---]

Parameters	**Gross Generation**	**P.L.F**	**Auxiliary Power Consumption**	**Specific Oil Consumption**	**Specific Coal Consumption**	**Heat Rate**	**GCV**	**SPM**	**SOx**	**NOx**	**Condenser Vacuum**
PERIOD	MU	%	%	ml/kWh	kg/kWh	kCal/kWh	kCal/kg	mg/Nm^3	µmg/m^3	µmg/m^3	mm of Hg (abs)
Pre R&M [Yearly for 3 Years]											
Post R&M [Monthly/ Yearly up to 3 Years]											

5. Problems/challenges faced in O&M after implementation of R&M

S. No.	Area	Problems/challenges faced after implementation of R&M interventions	Remedial Measures taken/Suggested
(i)	**Boiler**		
(ii)	**Turbine**		
(iii)	**Generator**		
(iv)	**Ash Handling System**		
(v)	**C&I system**		
(vi)	**Information Technology systems**		
(vii)	**Safety**		
(viii)	**Pollution control**		