

CenPEEP

Performance Optimiser

(Optimisation by using state-of-the-art technologies & practices)



March 2003

CENTRE FOR POWER EFFICIENCY AND ENVIRONMENTAL PROTECTION



Studs being opened using Eddy Current Induction Heating Technique

NTPC-CenPEEP INTRODUCES 'EDDY CURRENT INDUCTION HEATING' FOR QUICK OPENING / CLOSING OF STUDS & CAPNUTS OF STEAM TURBINE HORIZONTAL JOINT THEREBY SAVING TIME AND MONEY

"Eddy Current Induction Heating" Is Internationally Accepted As An Effective Technique For Turbine Studs & Capnuts Heating, Requiring Only Fraction Of Time Normally Needed For Opening / Closing. Adopting This Technique, Indian Utilities Have Demonstrated Saving Of 36-48 Hours In A 210 Mw Unit During Overhaul

DEMONSTRATED BENEFITS

- **Substantial reduction in time for opening / closing of Turbine Studs & Capnuts (typically reducing time from 30 minutes to 4 minutes for one stud / cap nut).**
- **Estimated increase in unit Availability by 36-48 hours.**
- **Increased profit through more power generated, 7 - 10 million units from a 210 MW unit.**
- **Process is Safe, Quick, Convenient and Efficient.**

OBJECTIVE

The increasing emphasis on availability and reliability of Power Plant operation and simultaneously keeping the lowest possible cost of generation is a challenge to Power sector. It has resulted in adoption of new approaches to maintenance and overhauling of critical components in Power Plants worldwide. Out of all the main activities during a unit overhaul

at a power plant, the Turbine overhauling generally remains on critical path. Therefore, the savings that could result by cutting down the duration of Turbine overhaul can ultimately bring down the overall unit outage time.

In Turbine overhauling the time taken for opening / closing of High Pressure (HP) and Intermediate Pressure (IP) Turbine horizontal joint studs & capnuts is quite significant. The key challenges for achieving

effective performance in this area are:

- Reducing duration for opening / closing of studs & capnuts.
- Improving quality of work.
- Safe and reliable process.

This performance optimiser deals with an effective technique for quick opening / closing of turbine horizontal joint studs & capnuts.

RESPONSE

CONVENTIONAL TECHNIQUE

Most of the Power Utilities currently use Cartridge heaters / Torch heating for opening / closing of HP and IP Turbine Studs. The time taken by this method is about 30 minutes for opening and 20 minutes for closing of each stud / capnut. The efficiency of heating by conventional means is very low due to convection and radiation heat loss. The gas heating

CenPEEP awarded Climate Technology Initiative (CTI) award 2002 by International Energy Agency, Paris

has its own inherent safety concerns. The longer duration of heating the stud /capnut leads to heating of horizontal joint of cylinder. In view of this, the surface of the cylinder is susceptible to warping. With this technique, there are chances that the studs / capnuts may be required to be cut in case of not opening.

NEW TECHNIQUE

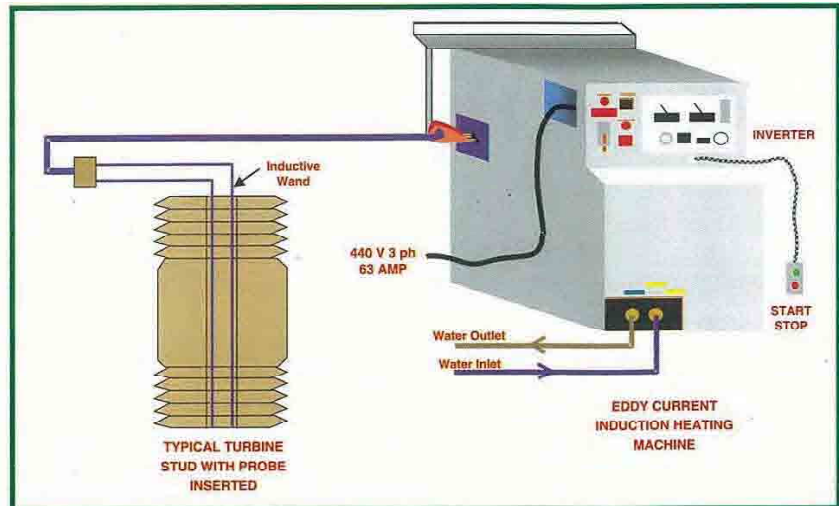
Principle – The process of opening and closing of turbine stud & capnut utilizes a method of induction heating to perform the task. The process reduces the time to a fraction of that normally taken by conventional methods i.e. cartridge heaters or torch heating.

In this process the Electromagnetic induction heating utilises the principle that when a mass of conductive material is exposed to an alternating magnetic flux, eddy currents are set up in the mass. The energy generated by the flow of these eddy currents through a conductive mass, with a given resistance, dissipates as heat and conforms to I^2R losses.

Induction heating of magnetic steel has an added benefit through a phenomenon known as hysteresis losses i.e. the power losses needed to change direction of a magnetic flux.

Induction heating has the capability of producing much greater watt densities to the inside of the studs of the order of 5 times that of cartridge heaters. Induction heating also overcomes the problems associated with film coefficients related to cartridge and torch heating i.e. the capability of the surface of the stud / capnut to transfer the heat to which it is exposed. With induction heating the heat is generated within the stud / capnut itself, thereby having much more mass heated by which thermal conduction can take place.

Operation – The system consists of



ADVANTAGES OF NEW TECHNIQUE

- The process is **very efficient** since induction heating generates heat within the body of Stud / Capnut.
- The **rapid heating process** without heating the shell, virtually eliminates warping of horizontal joint and potential for steam leak.
- Utilizing the high frequency power supply, stud / capnut is heated between threaded area to avoid thread distortion, thereby **no need to cut stud / capnut**.
- Opening / Closing process is very quick, total **time saved** in case of 210MW unit is **36-48 Hours**.
- Technology & Equipment are **proven and reliable**.
- Process is **safe** as no external heat source is needed.

an Inductive Wand placed in the center of a Turbine stud / capnut. The inductor is connected by a single cable to an induction cabinet of 100 or 200 KW size. The inductive wand is supplied with power at less than 100 volts from the induction cabinet for heating the stud / capnut. As the stud / capnut is heated, gradual expansion takes place. Heating continues until sufficient expansion

has been achieved to allow easy stud / capnut loosening / tightening. The expansion process in general takes about four to five minutes per stud / capnut. The process does not require heavy hammer for opening / closing of stud / capnut. During the process of heating, the water supply through the set up to the wand and other parts of the machine is maintained to keep the whole system to work efficiently.

Site Requirements

Power - 440 volt, 3 phase, 63 amp

Water - Machine requires water supply which can provide 35 liter per minute at 3kg/sq.cm with adequate drainage facility.

Support - Scaffolding around the Turbine area.

CenPEEP PERSPECTIVE

CenPEEP is working with USAID, USDOE and other US agencies for achieving the objective of Greenhouse Gas reduction through performance optimisation of thermal power plants in India. This new technique for Quick opening / closing of Turbine studs & capnuts by Eddy Current Induction Heating has been successfully used by majority of leading utilities in USA. CenPEEP facilitated demonstration of this new technique at NTPC stations.

CenPEEP selected for Climate Protection award 2003 by Environmental Protection Agency, USA

TYPICAL CASE STUDY

210MW LMZ Turbine - Time Taken in Opening / Closing of HP / IP Turbine Horizontal Joint Studs

Sl. No.	Stud Size x Length (in mm)	Number of Studs (nos.)	CONVENTIONAL METHOD Average Time (approx.) for one Stud (minute)		EDDY CURRENT INDUCTION HEATING Average Time (approx.) for one Stud (minute)	
			Opening	Closing	Opening	Closing
HP TURBINE						
1	M 140x810	08	40	20	05	05
2	M 140x710	02	40	20	05	05
3	M 120x760	04	35	20	05	05
4	M 100x705	12	30	15	04	05
5	Pin Bolt M 100x930	04	40	20	04	05
IP TURBINE						
1	M 100x690	16	25	15	04	04
2	M76x635	08	20	15	03	04
3	Pin Bolt M76x870	07	25	15	03	04

Highlights of Saving from Case Study

Description	Conventional Method	Eddy Current Induction Heating	Saving in Time
• Total time for opening of HP & IP Studs	32 hrs 35 min	4 hrs 43 min	27 hrs 52 min
• Total time for closing of HP & IP Studs	16 hrs 45 min	4 hrs 34 min	12 hrs 11 min
• Seizure of studs at the time of opening	Generally 1-2 studs get stuck up/seized	No seizure of studs	-----

This technique is also being used for brazing, thermal expansion of shrunk fit components such as retaining ring of Generator rotor, insitu heat treatment of weld repairs on Turbine rotor

Efficient & Safe Technique for Increased Availability and Generation

Performance Optimisation Group (POG) for Sustainable Improvement in Availability & Performance

CenPEEP has conducted and continues to demonstrate and disseminate state of the art technologies & best practices for power plant performance optimization and availability improvement. This was followed by formation of Performance Optimisation Groups (POG) in key areas. It has resulted in establishing a self sustaining system to provide insight into problem areas and take actions for availability and performance improvement. Based on CenPEEP experience it is felt that POGs should be formed in key areas. Given below are the expected benefits of POG :

Objectives:

- Improvement in Availability & Performance
- Thrust on key areas / equipment like Condenser, Mills & Combustion, Generator Transformer, Electrostatic Precipitator
- Identification of problem areas
- Action Plan
- Introduction of New Technologies
- Awareness and participation of all

Methodology :

- Identification of a co-ordinator
- Developing multidisciplinary forum of concerned area
- Periodic meetings
- Discussion and analysis of performance data
- Developing action plan
- Evaluating and fixing new targets for improved performance
- Performance assessment before and after overhaul
- Study of operating methodology
- Identification of issues for management attention
- Quality checks during maintenance
- Organizing workshops and seminars

Benefits :

- Sustained Availability & Efficiency Improvement
- Upgradation of technology
- Upgradation of instruments
- Benchmarking of performance
- Gains through change in operating methodology
- Quick decision and implementation

**Awarded
Climate
Technology
Initiative
(CTI)
Award 2002**

**Selected
for
EPA 2003
Climate
Protection
Award**

Performance Optimiser No. : PO-EF-3003 (March, 2003)

Address for Correspondence : General Manager;
Centre for Power Efficiency & Environmental Protection (CenPEEP), NTPC, R&D Building,
A-8A, Sector-24, Noida 201301, (UP), INDIA
Tel. : 91-120-2410316, Fax : 91-120-2410322, E-mail : deosharma@ntpceoc.co.in
Web site : <http://www.ntpc.co.in/otherlinks/cenpeep.shtml>

CENPEEP

Performance Optimiser

(Optimisation by using state-of-the-art technologies & practices)



March 2002

CENTRE FOR POWER EFFICIENCY AND ENVIRONMENTAL PROTECTION



NTPC - CENPEEP INTRODUCES MULTIPLE TECHNOLOGY BASED GENERATOR TRANSFORMER PREDICTIVE DIAGNOSTICS PROGRAM FOR RELIABLE CONDITION ASSESSMENT OF EQUIPMENT

Multiple technologies, including portable equipment & laboratory based methods and integration of results reveal the information on transformer condition that is more comprehensive. It has enabled implementing Stations to 'time' the maintenance and reduce maintenance & equipment failures.

BENEFITS

- Integrated methodology employing latest methods of ultrasonic inspection for partial discharge, infrared thermography, dissolved gas analysis in oil, sound level, vibration spectrum analysis and other techniques for periodic monitoring of critical equipment like Generator Transformers, *provides more reliable feedback on equipment condition.*
- Program helps avoid transformer failures & forced outage and plan maintenance activity & spares needed in advance as demonstrated in Pilot Program at selected Stations.
- Avoided costs of over Rs. 4.5 crores estimated .
- Integrated diagnostic program implementation can realize full potential benefits.

OBJECTIVE

Generator Transformer, a stationary equipment with no standby, is a critical link between generator and transmission system. Its continued reliable operation is crucial for uninterrupted power delivery. Presently, for this vital equipment, some utilities have a defined evaluation program based on 'off-line' electrical tests. Some have combined periodic oil screening and evaluation of 'Dissolved Gases in oil Analysis (DGA)' program to detect degradation mechanisms, identify type, source and severity of problem. There are instances when no definite faults could be located on inspection triggered by high rise in fault gases; sometimes repairs are carried out but the trend of rising fault gases continues. There are times when transformer fails without any warning signals. To address these concerns, there is need for more information about the fault location and rate of progression.

RESPONSE

Comprehensive Transformer Predictive Diagnostics Maintenance (PDM) Program incorporates multiple technologies which complement each other and evaluates condition of each component of the system. It integrates such evaluation which provides more information about the faults, their probable location, severity and some times much earlier. Indications by multiple technology provide more confidence in diagnostics information. Condition based maintenance system helps schedule maintenance based on actual condition during planned unit overhauls. This avoids 'failures' and 'forced outages' thereby improving reliability and availability of equipment.

Eco-friendly power and greenhouse gas reduction through performance optimisation

CENPEEP PERSPECTIVE

CENPEEP is closely working with USAID, USDOE, EPRI, TVA and other US Agencies for achieving the objective of Greenhouse Gas reduction through performance & maintenance optimization of power plants in India. Comprehensive Generator Transformer Predictive Diagnostics Maintenance Program was developed by EPRI- M&D Centre and has been used successfully by many leading utilities in USA. These techniques were demonstrated with USAID / USDOE support at NTPC Stations. Pilot Program have been initiated at NTPC-Dadri, Rihand & Vindhyachal. Case studies have demonstrated the feasibility and utility of approach and potential for forced outage reduction, increased reliability & availability of transformers. This 'Performance Optimiser' deals with the elements of the program and illustrative case studies.

CONCEPT

Reliability of each component is essential to ensure reliability of whole equipment. Each component of the transformer from - **bushing to bushing**- including coolers, fans, pumps, controls, radiators & on load tap changers are evaluated with applicable multiple technologies as per the Equipment-Technology Matrix.

Ultrasonic noise/ Partial Discharge analysis (contact method) is applied to transformer using a high frequency fault detector (20 KHz to 250 KHz) to accurately detect partial discharge (PD). By monitoring peak amplitude of stress signal resulting from the PD bursts, it is possible to determine approximate location of PD and its severity. The portable device receives these ultrasonic emissions and provides the facility to listen to heterodynamically converted high frequency activities like 'popping', 'buzzing' or 'beacon frying' sounds, enabling detection of internal transformer problems without interference from high external electrical & mechanical noise levels. Random non periodic activity is caused by charge buildup & discharge between two points- generating ultrasonic (acoustic) signals as well as combustible gases. It is a very sensitive technique and possibly the first indicator of impending problems. When non periodic random events are heard, analysis of type of gases in oil and their levels is required.

Dissolved Gas Analysis (DGA): Gases are generated in oil filled transformers by thermal decomposition of oil & insulation either due to conductor losses or exposure to arc temperatures. Much research has been dedicated to study relationship between dissolved gases and transformer problems. Fair amount of success has been achieved in establishing a link between the

Table : Equipment - Technology Matrix for Transformers

Equipment	Ultrasonic Test		IR Therm.	Vibration	Sound	DGA	Special Tests	Visual
	Contact	Air borne						
MAIN TANK	Y	Y	Y	Y	Y	Y	X	Y
PUMP	Y	X	Y	Y	X	X	FLOW	Y
FANS/ RADIATOR	X	X	Y	X	X	X	X	Y
BUSHINGS	X	Y	Y	X	X	X	X	Y
CONTROL CABINET	X	Y	Y	X	X	X	X	Y
OLTC	Y	X	Y	X	X	Y	X	Y

specific fault gases & fault types, common fault gases-their concentrations & ratios, and the nature and severity of transformer fault. It is presently most commonly used technology for transformer diagnostics despite its inherent limitation in identifying the location of faults with certainty. Complimentary technologies like ultrasonic noise/PD analysis & IR thermography help in overcoming this limitation to a reasonable extent.

Infrared Thermography (IRT) is the most versatile tool. With high-resolution devices now being available, imaging reveals thermal patterns on transformers, transformer-cooling system, on load tap changer, pump, motors, bushings, control cabinets. Knowing changes in thermal patterns and comparing this information with data obtained from other technologies such as oil analysis and ultrasonic noise / PD analysis contributes significantly to condition assessment.

External **vibration measurements and spectrum analysis** on energized transformer can indicate changing winding condition, mechanical looseness of clamps on the core & windings (if any) and bearing wear in pumps. Baseline signatures are essential and with age, deterioration in patterns can be easily detected by trending. When vibration patterns are found abnormal, data from other

diagnostics techniques is used to complement the observation like rise in hot metal gases or low level partial discharges or when windings are deformed, sound levels may rise. Documenting overall **sound levels** exactly at the same location is valuable in indicating the gross abnormality and a need for further investigation. **Air borne** acoustic detection device detects corona in bushings and contacts in control cabinet.

Visual inspection is the most important technology being used by all engineers and observations require to be documented for any unusual sounds, discolorations, leaks etc.

Baselining of transformer condition with all technologies at usually operated maximum loads is vital as a reference. Measurements by all technologies at similar reference conditions, at same time, is important for arriving at meaningful correlations. Trending at periodic intervals helps in detection of abnormal patterns and interpretation of developing faults & their severity. Knowledge of transformer internals is important for deciding about the faulty components and repair action.

The constitution of interdisciplinary team is vital to management of technologies & Program. The team will also help in integrating the multiple technology based approach with DGA & off line electrical tests.

'Health of each component is a measure for health of total equipment'

CASE STUDY 1 DETECTION OF INTERNAL MECHANICAL LOOSE PART IN 210 MW GT

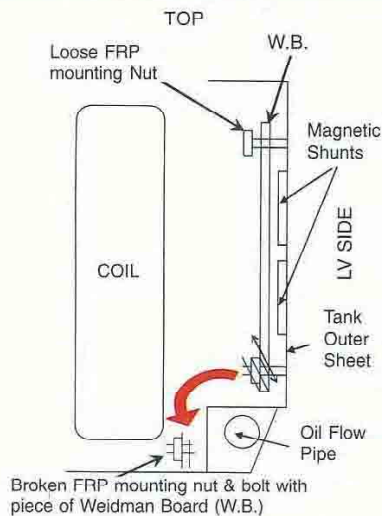


Figure 1

PDM Survey with multiple technologies leads to detection of acoustic activity on LV side and location of source near parting plane (Fig.1).

- Mechanical nature of acoustic activity, absence of fault gases and correlation indicated non electrical nature of fault.
- Additional vibration measurements on source location indicated mechanical looseness.
- On review of internal details, Weidman Board looseness suspected.

INTERNAL INSPECTION DURING PLANNED OVERHAUL REVEALED VIBRATING WIEDMAN BOARD AT THE LOCATION DUE TO BROKEN FIBRE GLASS MOUNTING NUT AND BOLT (FIG. 1).

Repair eliminated the abnormal ultrasonic activity & vibration pattern in post repair PDM-survey.

CASE STUDY 2 DETECTION OF LOW LEVEL THERMAL FAULTS IN 210 MW GT

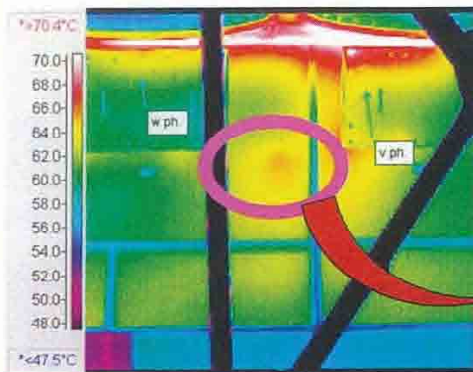


Figure 2



Figure 3

- Base line established with multiple technologies. No gas norms violation in DGA. Locations of acoustic activity recorded.
- Thermal hot spots detected on LV side by IRT with reference to base line (Fig.2). DGA analysis showed normal ageing by CIGRE method & overheating by IEEE method during next periodic PDM survey.
- Acoustic activity increased on LV side, temperature of hot spots increased by 2 deg C in a fortnight, location coincided with high acoustic activity, DGA sampling and analysis recommended.
- DGA indicated rise in fault gases though overall gases within norms, low thermal faults (150 deg C) indicated by IEEE & CIGRE method.
- Presence of thermal faults

concluded by correlating the data on technology matrix, faults on LV side at specific locations of high acoustic activity & high temperature and faults progression though not critical.

INSPECTION DURING ANNUAL OVERHAUL REVEALED LOOSE BOLTS ON LV BUS BAR (FIG 3).

Repair eliminated the thermal fault indication & acoustic activity on surface and DGA indicated normal ageing.

Multiple Technologies, Periodic measurements and Trending are key to PDM

AVOIDED COSTS CALCULATION FOR ILLUSTRATED CASES

	Case: 1 Failure Modes	Case: 2 Failure Modes
Catastrophic (worst case)	0.01% Probability <ul style="list-style-type: none"> • Catastrophic • Coil replacement • New transformer • Forced outage: Generation loss min 25 days 	0.1% Probability <ul style="list-style-type: none"> • Catastrophic • Coil/bus bar replacement • New transformer • Forced outage: Generation loss min 25 days
Moderate (possible)	10% Probability <ul style="list-style-type: none"> • Outage for corrective inspection • Time for spare identification • Coil Insulation damage • Wiedman board replacement • Forced outage: Generation loss min 10 days 	10% Probability <ul style="list-style-type: none"> • Outage for corrective inspection • Time for spare identification • Bus bar damage • Insulation damage • Forced outage: Generation loss min 25 days
Minor (best case)	89.99% Probability <ul style="list-style-type: none"> • Tripping of transformer • Inspection & minor repair of Wiedman board • Forced outage: Generation loss min 5 days 	89.9% Probability <ul style="list-style-type: none"> • Rise in DGA • Tripping of transformer • Inspection & minor repair • Forced outage: Generation loss min 10 days
Total estimated costs	Rs. 98.7 lakhs	Rs.189 lakhs
Actual work done	<ul style="list-style-type: none"> • Inspection & repair during annual overhaul • Replacement of FRP bolt/nut • Repair of Wiedman Board • Generation loss: nil 	<ul style="list-style-type: none"> • Inspection during annual overhaul • Tightening of bolts & minor insulation repair • Generation loss: nil
Actual costs incurred	Rs. 12 lakhs	Rs.16 lakhs
Avoided costs	Rs. 86.7 lakhs	Rs.173 lakhs

Basis for cost-benefit calculation

- Follows EPRI Model based on probabilistic assessment
- Benefit is difference between 'cost of what could have occurred vs actual cost of repair job with PDM'.
- Conservative but realistic assessment; not based on catastrophic failure alone, realistic as it accounts for possibilities of different scenarios: probabilities range taken as 0.01 to 1.0% for catastrophic, max 10% for moderate and rest is minor as the most probable.; Total of all probabilities is 100, probabilities are assigned based on experience.

Key Elements of Predictive Diagnostics Maintenance Program

1. 3Ds: *Detection, Diagnosis and Documentation* are basic components of PDM .
2. Multidisciplinary 'Performance Optimization Group (POG) '.
3. Program to be comprehensive: review of existing data, need for additional data and application of other complimentary technologies.
4. Equipment-Technology Matrix to be developed for each system / equipment
5. Reliability and correctness of data is vital.
6. Baseline of condition, periodic data collection and trending is essential for interpretation.
7. Communication & visibility are the key to success.
8. Training of personnel in techniques and diagnostic system is important.

Predictive Diagnostic Maintenance is an attitude and not a technology

Performance Optimiser No. : PO-EF-1002 (March, 2002)

Address for Correspondence : Addl. General Manager (Incharge); Centre for Power Efficiency & Environmental Protection, NTPC, R&D Building,
A-8-A, Sector-24, NOIDA 201 301 (UP) India Tel. : 91-118-4410316
Fax : 91-118-4410322 Web site : <http://www.ntpc.co.in>