IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Performance Prediction Methods for Reducing Losses in Intermediate Pressure Steam Turbine by Using Steam Path Appraisal

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Abstract

Quality of fuel is of paramount importance for producing quality of steam which finally affects the performance of thermal power plant. This not only hampers the performance of turbine but also helps to reduce the maintenance, overhauling, and increase the time span of breakdown maintenance schedule. Worldwide, 35 % share of power generation is fulfilled through steam turbine in thermal power plant, and hence steam path appraisal is significant to predict the efficiency of turbine in varying fuel application.

The paper presents the performance predication methods for reduction of losses which occurred in intermediate pressure steam turbine. The basic theory of the turbine steam path flow, pressure and temperature relationships is reviewed to realize the understanding of how these trends can be interpreted and used to locate and identify the cause of the turbine deterioration. This is necessary to identify the specific components which affect the thermal performance of steam turbine.

Keywords: - IP Turbine, Steam path, steam losses, Performance

Introduction

For steam turbine to operate at its optimum level of thermal performance, it must achieve a high initial level of performance and must be able to sustain thermal performance over time. This is best achieved by an ongoing program of evaluation and assessment of thermal performance data. This steam path appraisal has a three purpose. The first is to detect deterioration in the thermal performance by trending changes in various performance parameters. The second is to identify the cause of performance degradation by proper data evaluation and interpretation. The third is to develop cost-effective solutions to correct operational and equipment problems, which contribute to the degradation in thermal performance. To meet these objectives, a thermal performance program should include the following essential factors:

- Obtain baseline performance data on individual turbines and cycle components during initial operation and after a maintenance outage to establish a base for indentifying specific areas of performance losses.
- Periodic acquisition of repeatable performance data.
- Proper evaluation and assessment of performance data so that deterioration can be detected, located, trended, and corrected in a cost effective manner.
- Detailed inspection of and quantification of the expected performance recovery from restoration of steam turbine path.

Steam Path Appraisal

During the maintenance overhaul the mechanical condition of the turbine, particularly the steam path components, must be established. A steam path appraisal is used to identify and quantify mechanisms contributing to unit damage. The appraisal effort can be enhanced significantly, and overhaul critical path avoided, if a data package is provided in advance of the unit opening. The data package should include, as a minimum, the following data:

- Steam cycle heat balance(s)
- Performance data collected as described in performance evaluation
- Turbine cross-section drawing
- Past inspection reports
- Past preventive maintenance records

- Past corrective maintenance records

A thorough review of the turbine performance and maintenance history is one of the most important aspects of the work. Corrective maintenance records, if properly analyzed, can provide useful trends of component failure and insight into root-cause of failure. Past problems tend to be repeated if not recognized, understood, and actively prevented. This same study is helpful in identifying where the existing test and analysis programs have failed to predict the observed condition of the unit. The study subsequently allows practical suggestions for improving the data monitoring systems. After the historical data has been reviewed and evaluated, the appraisal should be planned so that problems suggested by the review can be properly investigated.

Methodologies of Steam Path Appraisal

A. Steam Path Examination

A thorough examination of the critical areas in the steam path is essential to making informed judgments about the efficacy of current operating configurations and for making subsequent determinations about the need for changes to components, application of upgrades, or methods of operation. Exceptional effort should be made at this point to perform a complete and detailed observation of all critical areas and components. Every variation or out-of-character detail should be noted. Thoroughness at this point can save much time later during the evaluation period. A steam path examination should include, as a minimum, the following activities:

- Examine quality of blade profile.
- Identify mechanical damage.
- Identify steam path deposits.
- Identify erosion damage.
- Identify seal damage.
- Identify unusual damage.
- Identify and photograph damage.
- Measure and plot patterns of seal wear.
- Review start-up procedures and thermal gradients.
- Determine probability of distortion problems.

B. Evaluation of Steam Path Examination Data

Once the steam path examination is complete, a critical evaluation of the data obtained during the examination must be performed. This evaluation should address all potential mechanisms for damage phenomena observed during the examination. As a minimum, the following activities should be performed:

- Quantify losses caused by mechanical damage.
- Quantify losses caused by steam path deposits.
- Quantify losses caused by erosion.
- Quantify losses caused by excessive tip seal and packing leakages.
- Estimate magnitude and effect of efficiency losses.
- Estimate magnitude and flow capacity effect.
- Reconcile test results are consistent with apparent condition of steam path.
- Identify discrepancies between analysis test results and inspection.
- Develop method for improvement of analyses and diagnoses.
- Develop method for improvement of test procedures.
- Identify performance influencing phenomena, such as previous repair deficiencies or modified design practices.
- Discuss with operators, or other support personnel, specific start-up or operating conditions which might contribute to observed unit condition.

C. Prepare Recommendations and Reports

After the steam path examination and the data analysis have been completed, recommendations are made concerning the equipment configuration and operating conditions. In addition, the needs for changes in procedures or upgrade of components to improve the operating efficiency of the turbine are disseminated to the responsible parties. When preparing recommendations and reports, the flowing program is normally followed:

1. Generate recommendations for economically sound repairs; application Cation of component upgrades, and testing and analyses improvements.
2. Provide an oral report to interested personnel, including a discussion of recommended repairs and component upgrades.
3. Provide a written report containing the same detailed recommendations given orally.

Case Study

Because of the high cost associated with performing high-precision performance improvement, and due to the non-competitive nature of the power generation market until the very recent past; data confirming the theories presented above is typically unreliable. The case study below describes the inspection and procedures implemented to confirm the performance improvement of intermediate pressure steam turbine. The results of the reduced losses in Intermediate pressure steam turbine and inspection process indicate that the benefits were greater than had originally been anticipated.

The Interstage Packing

Interstage packing restricts the flow around the stationary blading, between the stationary blading and the rotor. The inter-stage packing work together with the root spill strips and balance holes, when present. Occasionally a clearance or other measurement is not available or use improperly during the data taking process. The usual action taken under these circumstances is to use the design clearance.

The opening audit loss due to increased inter-stage packing clearances was -29.7kW and the heat degrade -0.47kJ/kWh. The closing audit loss when compared to original design clearances was 41.4kW and the heat rate degrade 0.64 kJ/kWh.This has gain losses as clearance were not corrected in respect to design.

Table 1 Opening Audit of Total Interstage Packing for IPT casing

Description	**Power Loss kW**	**Change In G.T.H.R kJ/kWh**
IP Turb	-27.3	-0.43
IP Gen	-2.4	-0.04
Turbine Total	-29.7	-0.47

Table 2 Opening Audit of Interstage Packing for IP Casing

Description	**Leakage Flow Kg/s**	**Average Clearance Mm**	**Corrected Average Clearance Mm**	**Wear mm**	**Stage Efficiency Loss %**	**Power Loss kW**	**Change In G.T.H.R kJ/kWh**
Stage1	1.6622	0.781	0.781	-0.119	0.18	4.5	0.07
Stage2	1.1681	0.737	0.737	-0.161	-0.07	-1.9	-0.03
Stage3	1.4013	0.860	0.860	-0.040	0.09	2.6	0.04
Stage4	1.1535	0.676	0.676	-0.224	-0.11	-3.4	-0.05
Stage5	1.0905	0.667	0.667	-0.233	-0.12	-4.1	-0.06
Stage6	1.1868	0.813	0.813	-0.087	-0.03	-1.1	-0.02
Stage7	0.7961	0.560	0.560	-0.340	-0.17	-6.7	-0.10
Stage8	1.2120	0.968	0.968	0.068	0.06	2.5	0.04
Stage9	1.1474	0.997	0.997	0.097	0.08	3.4	0.05
Stage10	0.7806	0.729	0.729	-0.171	-0.05	-2.3	-0.04
Stage11	0.5685	0.529	0.529	-0.371	-0.15	-7.6	-0.12
Stage12	0.3435	0.316	0.316	-0.584	-0.24	-13.2	-0.20
Total						-27.3	-0.43

Table 3 Closing Audit of Total Interstage Packing for IPT casing

Description	**Power Loss kW**	**Change In G.T.H.R kJ/kWh**
IP Turb	-35.5	-0.55
IP Gen	-5.9	-0.09
Turbine Total	-41.4	-0.64

ISSN: 2277-9655
Impact Factor: 1.852

Table 4 Closing Audit of Total Interstage Packing for IP casing

Description	Leakage Flow Kg/s	Average Clearance Mm	Corrected Average Clearance Mm	Wear mm	Stage Efficiency Loss %	Power Loss kW	Change In G.T.H.R kJ/kWh
Stage1	1.3171	0.794	0.794	-0.106	-0.04	-1.0	-0.02
Stage2	1.1649	0.733	0.733	-0.167	-0.07	-1.9	-0.03
Stage3	1.3479	0.810	0.810	-0.090	0.06	1.7	0.03
Stage4	1.1535	0.676	0.676	-0.224	-0.11	-3.4	-0.05
Stage5	1.0870	0.664	0.664	-0.236	-0.13	-4.1	-0.06
Stage6	1.1868	0.813	0.813	-0.087	-0.03	-1.1	-0.02
Stage7	0.7944	0.559	0.559	-0.341	-0.17	-6.8	-0.11
Stage8	1.2098	0.965	0.965	0.065	0.06	2.4	0.04
Stage9	1.1202	0.995	0.995	0.095	0.06	2.6	0.04
Stage10	0.7716	0.729	0.729	-0.171	-0.06	-2.6	-0.04
Stage11	0.5606	0.527	0.527	-0.373	-0.15	-7.9	-0.12
Stage12	0.3381	0.314	0.31	-0.586	-0.24	-13.4	-0.21
Total						-35.5	-0.55

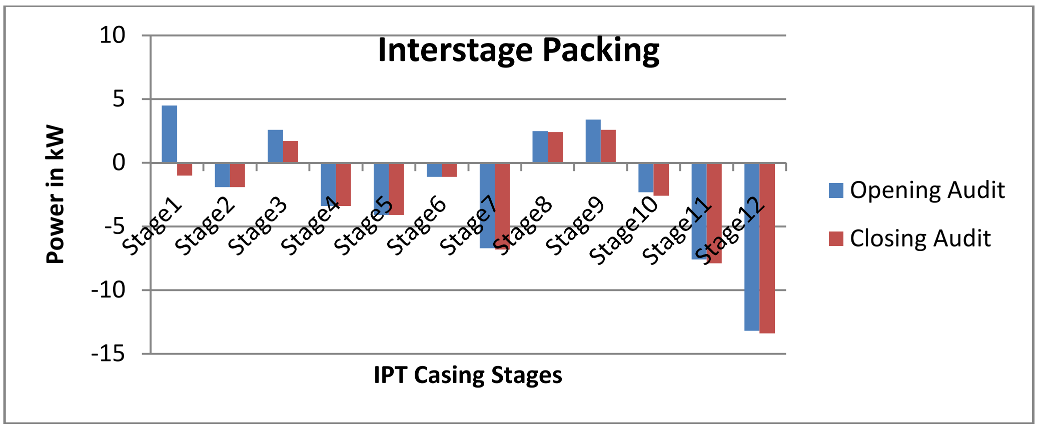

Figure 1 Opening Audit Vs Closing Audit for Inter Stages Packing of power losses in KW for IP casing

Table 5 Opening Audit of Total Interstage Packing for IPG casing

Description	Leakage Flow Kg/s	Average Clearance Mm	Corrected Average Clearance mm	Wear mm	Stage Efficiency Loss %	Power Loss kW	Change In G.T.H.R kJ/kWh
Stage1	1.1616	0.691	0.691	-0.209	-0.12	-2.9	-0.05
Stage2	1.5615	0.999	0.999	0.099	0.08	2.1	0.03
Stage3	1.5191	0.997	0.997	0.097	0.08	2.1	0.03
Stage4	1.2201	0.748	0.748	-0.152	-0.08	-2.3	-0.04
Stage5	1.4138	1.003	1.003	0.103	0.07	2.4	0.04
Stage6	1.1932	0.816	0.816	-0.084	-0.03	-1.1	-0.02
Stage7	1.4138	1.108	1.108	0.208	0.14	5.7	0.09
Stage8	1.0347	0.797	0.797	-0.103	-0.04	-1.6	-0.02
Stage9	1.0720	0.920	0.920	0.020	0.04	1.5	0.02

Stage10	0.8310	0.686	0.686	-0.214	-0.08	-3.6	-0.06
Stage11	0.9199	0.929	0.929	0.029	0.04	2.1	0.03
Stage12	0.5897	0.568	0.568	-0.332	-0.12	-6.8	-0.11
Total						-2.4	-0.04

Table 6 Closing Audit of Total Interstage Packing for IPG casing

Description	Leakage Flow Kg/s	Average Clearance Mm	Corrected Average Clearance mm	Wear mm	Stage Efficiency Loss %	Power Loss kW	Change In G.T.H.R kJ/kWh
Stage1	1.1599	0.689	0.689	-0.211	-0.12	-3.0	-0.05
Stage2	1.5601	0.997	0.997	0.097	0.08	2.0	0.03
Stage3	1.5164	0.994	0.994	0.094	0.07	2.1	0.03
Stage4	1.2185	0.746	0.746	-0.154	-0.08	-2.3	-0.04
Stage5	1.4138	1.003	1.003	0.103	0.07	2.4	0.04
Stage6	1.1932	0.816	0.816	-0.084	-0.03	-1.1	-0.02
Stage7	1.3606	1.055	1.055	0.155	0.11	4.3	0.07
Stage8	1.0347	0.797	0.797	-0.103	-0.04	-1.6	-0.02
Stage9	1.07254	0.921	0.921	0.021	0.04	1.5	0.02
Stage10	0.8092	0.683	0.683	-0.217	-0.09	-4.3	-0.07
Stage11	0.8979	0.927	0.927	0.027	0.03	1.3	0.02
Stage12	0.5736	0.565	0.565	-0.335	-0.14	-7.4	-0.12
Total						-5.9	-0.09

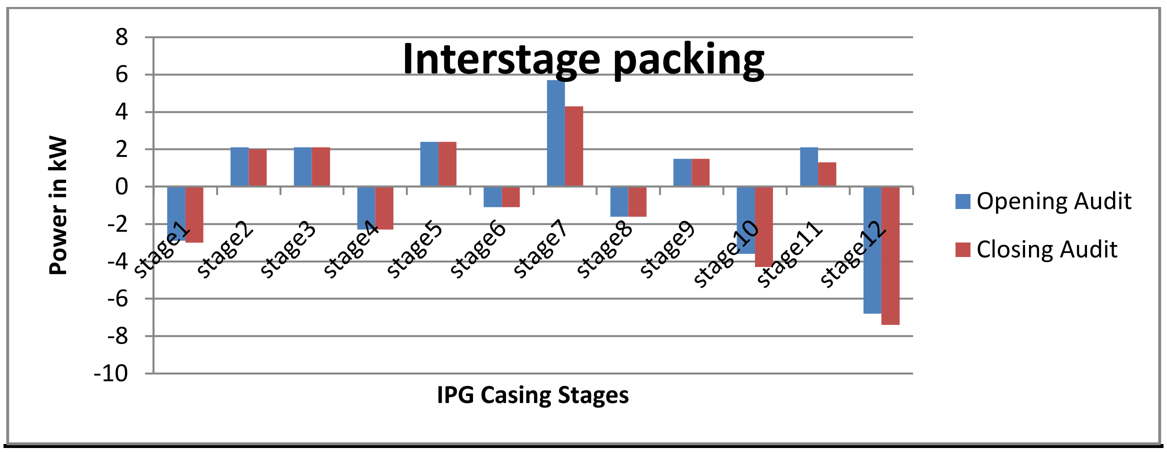

Figure 2 Opening Audit Vs Closing Audit for Inter Stages Packing of power losses in KW for IP casing

End Packing

Increased leakage from shaft end packing and their impact on heat rate and power output are summarized in the Shaft End Packing Audit result report. The loss reports provide the calculated leakage flow, measured average clearances, the wear, and the loss for each packing seal.

The opening audit loss due to increased end packing clearances was 141.1kW and the total heat rate degraded 2.19kJ/kWh.This closing audit loss due to increased end packing clearances was -141.1kW and the total heat degraded 2.19kJ/kWh.

Table 7 Opening Audit of Total Shaft End Packing for IPT casing

Description	Power Loss kW	Change In G.T.H.R kJ/kWh
IP Turb	49.2	0.76
IP Gen	91.9	1.43

Turbine Total	141.1	2.19

Table 8 Opening Audit of Total Shaft End Packing for IP casing

Packing Description	Seal	Leakage Flow Kg/s	Average Clearance mm	Corrected Average Clearance Mm	Wear mm	Power Loss kW	Change In G.T.H.R kJ/kWh
IP Exhaust(N3)	1	0.2354	0.964	0.964	0.464	51.7	0.80
	2	0.0544	1.133	1.133	0.633	-2.5	-0.04
	Total					49.2	0.76
Total						49.2	0.76

Table 9 Closing Audit of Total Shaft End Packing for IPT casing

Description	Power Loss kW	Change In G.T.H.R kJ/kWh
IP Turb	49.2	0.76
IP Gen	91.9	1.43
Turbine Total	141.1	2.19

Table 10 Closing Audit of Total Shaft End Packing for IP casing

Packing Description	Seal	Leakage Flow Kg/s	Average Clearance mm	Corrected Average Clearance mm	Wear mm	Power Loss kW	Change In G.T.H.R kJ/kWh
IP Exhaust(N3)	1	0.2354	0.964	0.964	0.464	51.7	0.80
	2	0.0544	1.133	1.133	0.633	-2.5	-0.04
	Total					49.2	0.76
Total						49.2	0.76

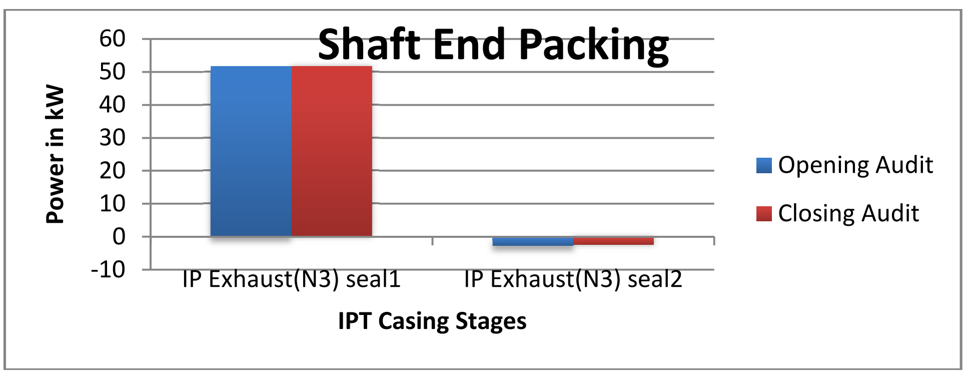

Figure 3 Opening Audit Vs Closing Audit for Shaft End Packing of power losses in KW for IP casing

Table 11 Opening Audit of Total Shaft End Packing for IPG casing

Packing Description	Seal	Leakage Flow Kg/s	Average Clearance mm	Corrected Average Clearance mm	Wear Mm	Power Loss kW	Change In G.T.H.R kJ/kWh
IP Exhaust(N4)	1	0.5556	0.622	0.622	0.122	103.4	1.61
	2	0.1942	1.384	1.384	0.884	-11.4	-0.18

	Total					91.9	1.43
Total						91.9	1.43

Table 12 Closing Audit of Total Shaft End Packing for IPG casing

Packing Description	Seal	Leakage Flow Kg/s	Average Clearance mm	Corrected Average Clearance mm	Wear mm	Power Loss kW	Change In G.T.H.R kJ/kWh
IP Exhaust(N4)	1	0.5556	0.622	0.622	0.122	103.4	1.61
	2	0.1942	1.384	1.384	0.884	-11.4	-0.18
	Total					91.9	1.43
Total						91.9	1.43

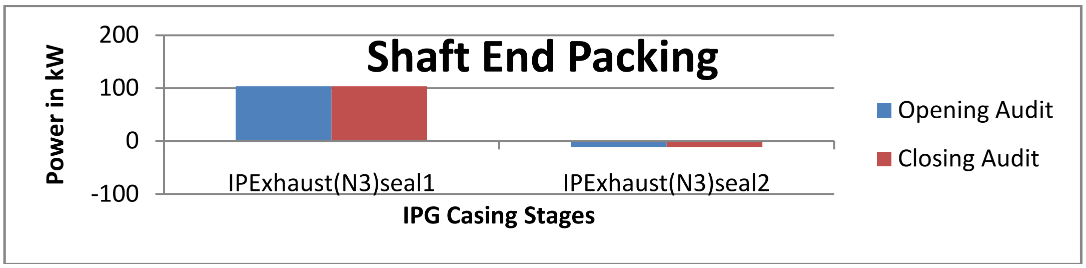

Figure 4 Opening Audit Vs Closing Audit for Shaft End Packing of power losses in KW for IP casing

Tip Spill Strips

Tip Spill Strips of IP casing was found rubbed & severe during opening. The Tip Spill Strips Audit Result Report summarizes the power output and heat rate degradation resulting from increased leakage past rotating blading and leakage losses for each turbine stage.

The opening audit loss due to increased Tip Spill Strips clearances was -6.4kW and the to heat rate degraded -0.09kJ/kWh.This closing audit loss due to increased Tip Spill Strips clearances was -11.2kW and the heat degraded -0.17kJ/kWh.

Table 13 Opening Audit of Total Tip Spill Strips for IPT casing

Description	Power Loss kW	Change In G.T.H.R kJ/kWh
IP Turb	-33.7	-0.52
IP Gen	27.3	0.43
Turbine Total	-6.4	-0.09

Table 14 Opening Audit of Total Tip Spill Strips for IP casing

Description	Leakage Flow Kg/s	Average Clearance Mm	Corrected Average Clearance Mm	Wear Mm	Stage Efficiency Loss %	Power Loss kW	Change In G.T.H.R kJ/kWh
Stage1	1.6328	0.948	0.948	-0.043	0.01	0.2	0.00
Stage2	1.7247	1.078	1.078	0.087	0.08	2.0	0.03
Stage3	1.4435	0.857	0.857	-0.133	-0.04	-1.1	-0.02
Stage4	1.2259	0.713	0.713	-0.278	-0.11	-3.4	-0.05
Stage5	0.8765	0.462	0.462	-0.529	-0.26	-8.4	-0.13
Stage6	1.2995	0.862	0.862	-0.129	-0.03	-1.1	-0.02
Stage7	0.8097	0.454	0.454	-0.537	-0.24	-9.7	-0.15
Stage8	0.9146	0.608	0.608	-0.383	-0.15	-0.6	-0.09
Stage9	0.8906	0.657	0.657	-0.333	-0.12	-5.0	-0.08

ISSN: 2277-9655
Impact Factor: 1.852

Stage10	1.0944	1.014	1.014	0.024	0.03	1.3	0.02
Stage11	0.7956	0.718	0.718	-0.273	-0.08	-3.9	-0.06
Stage12	0.8341	1.021	1.021	0.030	0.02	1.2	0.02
Total						-33.7	-0.52

Table 15 Closing Audit of Total Tip Spill Strips for IPT casing

Description	Power Loss kW	Change In G.T.H.R kJ/kWh
IP Turb	-35.5	-0.55
IP Gen	24.3	0.38
Turbine Total	-11.2	-0.17

Table 16 Closing Audit of Total Tip Spill Strips for IP casing

Description	Leakage Flow Kg/s	Average Clearance Mm	Corrected Average Clearance mm	Wear Mm	Stage Efficiency Loss %	Power Loss kW	Change In G.T.H.R kJ/kWh
Stage1	1.6131	0.948	0.948	-0.043	-0.00	-0.0	-0.00
Stage2	1.7040	1.078	1.078	0.087	0.07	1.8	0.03
Stage3	1.4262	0.857	0.857	-0.133	-0.05	-1.3	-0.02
Stage4	1.2111	0.713	0.713	-0.278	-0.12	-3.6	-0.06
Stage5	0.8660	0.462	0.462	-0.529	-0.26	-8.5	-0.13
Stage6	1.2838	0.862	0.862	-0.129	-0.04	-1.4	-0.02
Stage7	0.8000	0.454	0.454	-0.537	-0.25	-9.9	-0.15
Stage8	0.9035	0.608	0.608	-0.383	-0.16	-6.3	-0.10
Stage9	0.8906	0.657	0.657	-0.333	-0.12	-5.0	-0.08
Stage10	1.0944	1.014	1.014	0.024	0.03	1.3	0.02
Stage11	0.7956	0.718	0.718	-0.273	-0.08	-3.9	-0.06
Stage12	0.8341	1.021	1.021	0.030	0.02	1.2	0.02
Total						-35.5	-0.55

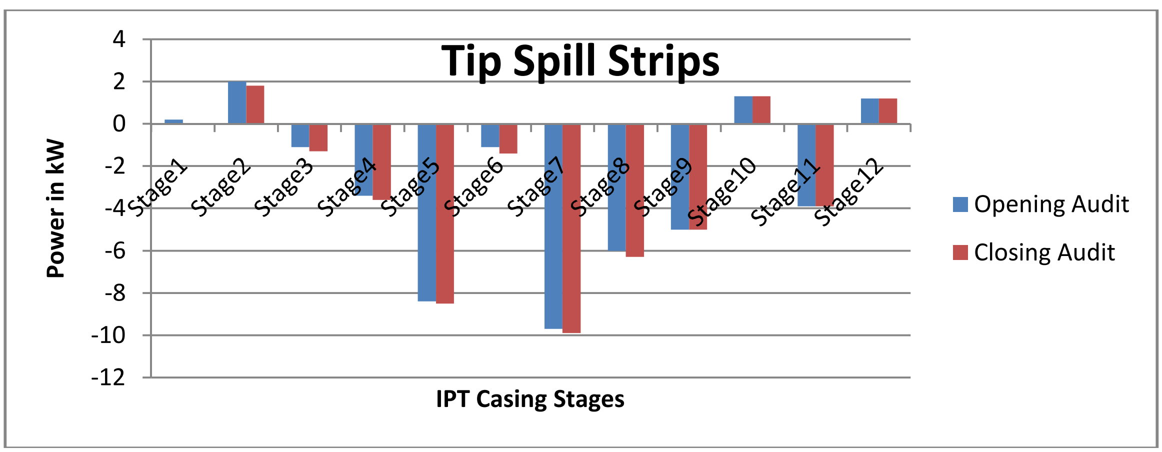

Figure 5 Opening Audit Vs Closing Audit for Tip Spill Strips of power losses in KW for IP casing

Table 17 Opening Audit of Total Tip Spill Strips for IPG casing

Description	Leakage Flow Kg/s	Average Clearance Mm	Corrected Average Clearance Mm	Wear Mm	Stage Efficiency Loss %	Power Loss kW	Change In G.T.H.R kJ/kWh
Stage1	2.0559	1.289	1.289	0.298	0.21	5.2	0.08
Stage2	1.222.8	0.645	0.645	-0.346	-0.16	-4.2	-0.07
Stage3	1.3769	0.800	0.800	-0.191	-0.07	-1.9	-0.03
Stage4	2.1331	1.565	1.565	0.575	0.32	9.7	0.15
Stage5	1.9501	1.446	1.446	0.456	0.25	8.3	0.13
Stage6	1.5099	1.083	1.083	0.092	0.07	2.5	0.04
Stage7	1.4002	1.024	1.024	0.033	0.04	1.5	0.02
Stage8	1.4193	1.013	1.013	0.022	0.03	1.4	0.02
Stage9	1.8384	1.618	1.618	0.627	0.32	13.2	0.21
Stage10	1.0511	0.827	0.827	-0.164	-0.04	-0.2	-0.03
Stage11	0.9398	0.803	0.803	-0.187	-0.05	-2.4	-0.04
Stage12	0.7420	0.718	0.718	-0.273	-0.07	-3.9	-0.06
Total						27.3	0.43

Table 18 Closing Audit of Total Tip Spill Strips for IPG casing

Description	Leakage Flow Kg/s	Average Clearance Mm	Corrected Average Clearance Mm	Wear mm	Stage Efficiency Loss %	Power Loss kW	Change In G.T.H.R kJ/kWh
Stage1	2.0311	1.289	1.289	0.298	0.20	4.9	0.08
Stage2	1.2081	0.645	0.645	-0.346	-0.17	-4.4	-0.07
Stage3	1.3603	0.800	0.800	-0.191	-0.08	-2.2	-0.03
Stage4	2.1331	1.565	1.565	0.575	0.32	9.7	0.15
Stage5	1.9501	1.446	1.446	0.456	0.25	8.3	0.13
Stage6	1.4918	1.083	1.083	0.092	0.06	2.2	0.03
Stage7	1.3833	1.024	1.024	0.033	0.03	1.2	0.02
Stage8	1.4022	1.013	1.013	0.022	0.03	1.0	0.02
Stage9	1.8163	1.618	1.618	0.627	0.30	12.7	0.20
Stage10	1.0384	0.827	0.827	-0.164	-0.05	-2.3	-0.04
Stage11	0.9285	0.803	0.803	-0.187	-0.05	-2.7	-0.04
Stage12	0.7330	0.718	0.718	-0.273	-0.08	-4.1	-0.06
Total						24.3	0.38

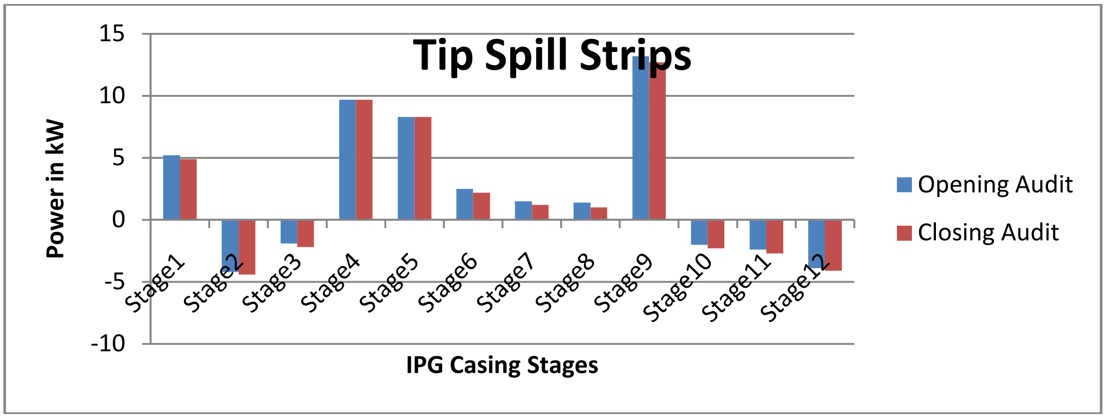

Figure 6 Opening Audit Vs Closing Audit for Tip Spill Strips of power losses in KW for IP casing

Surface Roughness

The Surface Roughness Turbine loss report summarizes the power output and heat rate degradation resulting from increased partition surface roughness and losses for each turbine stage. Light deposits, solid particle erosion and mechanical damage all contributed to an increase in surface roughness. The opening audit evaluation of the surface roughness showed a loss of 2521.2kW and an increase in heat rate of 39.32.Surface Roughness of closing audit loss when compared to original design was 2073.1kW and an increase in heat rate of 32.32kJ/kWh. COH recovered 5221.6Kw.

Table 19 Opening Audit of Total Surface Roughness for IPT casing

Description	**Power Loss kW**	**Change In G.T.H.R kJ/kWh**
IP Turb	1274.5	19.88
IP Gen	1246.7	19.44
Turbine Total	2521.2	39.32

Table 20 Opening Audit of Total Surface Roughness for IP casing

Description	**Stage Efficiency Loss %**	**Power Loss kW**	**Change In G.T.H.R. kJ/kWh**
Stage1	2.85	70.8	1.10
Stage2	3.10	81.3	1.26
Stage3	3.28	92.7	1.44
Stage4	3.08	92.6	1.44
Stage5	2.93	95.5	1.49
Stage6	2.77	98.5	1.53
Stage7	2.22	88.2	1.37
Stage8	2.68	105.2	1.64
Stage9	2.96	125.6	1.95
Stage10	2.05	95.6	1.49
Stage11	3.08	156.9	2.44
Stage12	3.14	171.7	2.67
Total		1274.5	19.88

Table 21 Closing Audit of Total Surface Roughness for IPT casing

Description	**Power Loss kW**	**Change In G.T.H.R kJ/kWh**
IP Turb	1019.2	15.89
IP Gen	1053.9	16.43
Turbine Total	2073.1	32.32

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Table 22 Closing Audit of Total Surface Roughness for IP casing

Description	Stage Efficiency Loss %	Power Loss kW	Change In G.T.H.R. kJ/kWh
Stage1	1.85	45.9	0.71
Stage2	2.07	54.3	0.84
Stage3	2.41	68.0	1.06
Stage4	2.35	70.8	1.10
Stage5	2.58	84.3	1.31
Stage6	2.36	83.7	1.30
Stage7	1.83	72.7	1.13
Stage8	2.48	97.3	1.51
Stage9	2.49	105.9	1.65
Stage10	1.59	74.4	1.16
Stage11	2.44	124.1	1.93
Stage12	2.52	138.0	2.15
Total		1019.2	15.89

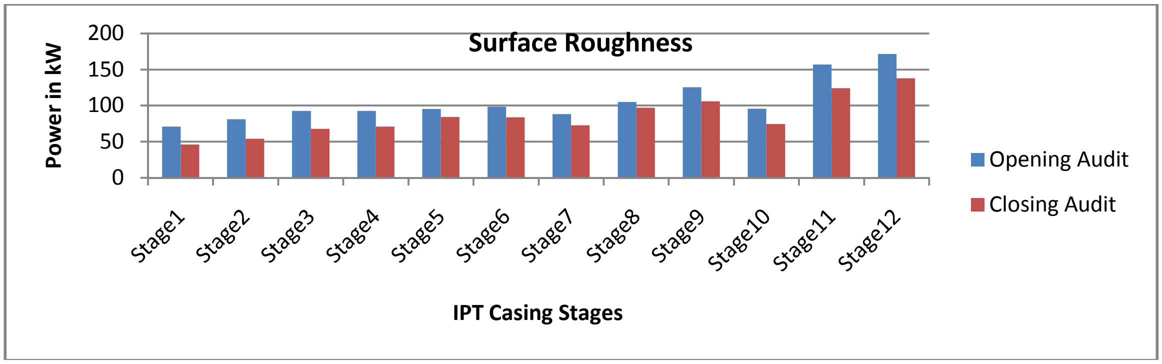

Figure 7 Opening Audit Vs Closing Audit for Surface Roughness of power losses in KW for IP casing

Table 23 Opening Audit of Total Surface Roughness for IPG casing

Description	Stage Efficiency Loss %	Power Loss kW	Change In G.T.H.R. kJ/kWh
Stage1	2.62	65.4	1.02
Stage2	2.72	71.8	1.12
Stage3	2.97	84.5	1.31
Stage4	2.92	88.4	1.38
Stage5	3.13	102.7	1.60
Stage6	2.77	98.9	1.54
Stage7	2.12	84.5	1.32
Stage8	2.92	115.6	1.80
Stage9	3.27	136.7	2.13
Stage10	1.97	90.5	1.41
Stage11	2.87	144.4	2.25
Stage12	2.97	163.3	2.54
Total		1246.7	19.44

 ISSN: 2277-9655
Impact Factor: 1.852

Table 24 Closing Audit of Total Surface Roughness for IPG casing

Description	Stage Efficiency Loss %	Power Loss kW	Change In G.T.H.R. kJ/kWh
Stage1	1.73	43.2	0.67
Stage2	1.84	48.5	0.76
Stage3	2.38	67.5	1.05
Stage4	2.35	71.4	1.11
Stage5	2.73	89.6	1.39
Stage6	2.50	89.2	1.39
Stage7	1.97	78.9	1.23
Stage8	2.78	110.1	1.71
Stage9	2.75	115.2	1.79
Stage10	1.55	71.4	1.11
Stage11	2.51	126.1	1.96
Stage12	2.60	142.8	2.22
Total		1053.9	16.43

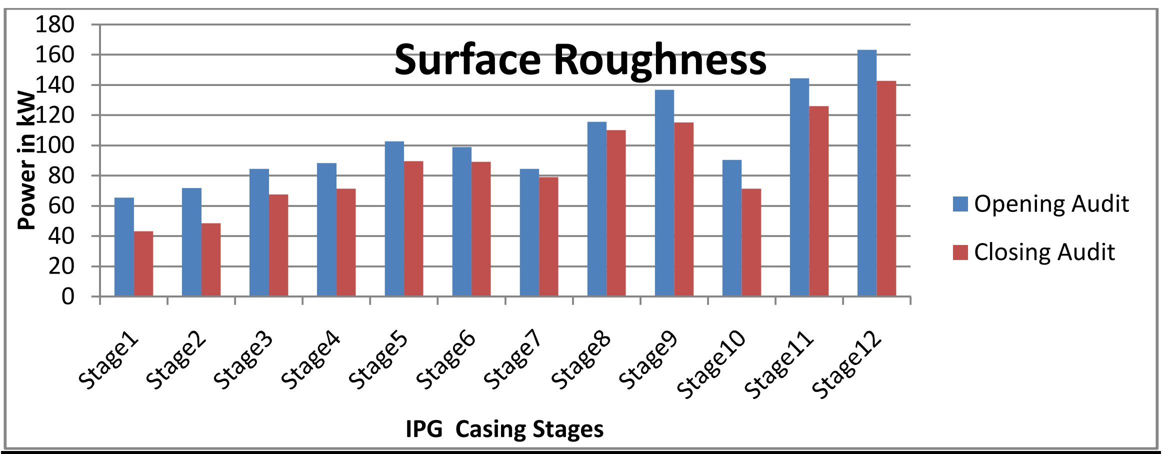

Figure 8 Opening Audit Vs Closing Audit for Surface Roughness of power losses in KW for IP casing

Result and Discussion

The change in Power Loss is the calculated decrease in gross output power, including generator and mechanical losses, for the stage or casing noted on the report. The Change in Heat Rate is the degradation in the gross turbine heat rate for the unit. The Total Change in Power Loss is a summation of the stage power losses from individual loss categories. The Total Change in Heat Rate is not; however, a summation of the heat rate changes from individual categories. The change in heat rate is a function of the power loss. This function is non-linear with respect to the power and, therefore, cannot be summed in a linear manner. The Change in Heat Rate is the degradation in the gross turbine heat rate resulting from the specific power loss and change in boiler duty, if any.

Table 25 Remaining loss in IP TE Turbine after Capital overhauling

Sr.no	Losses	kW	kJ/kWh
1	Interstage Packing	-35.5	-0.55
2	Tip Spill Strips	-35.5	-0.55
3	Shaft end packing	49.2	0.76
4	Surface roughness	1019.2	15.89
	Total	997.4	15.55

ISSN: 2277-9655
Impact Factor: 1.852

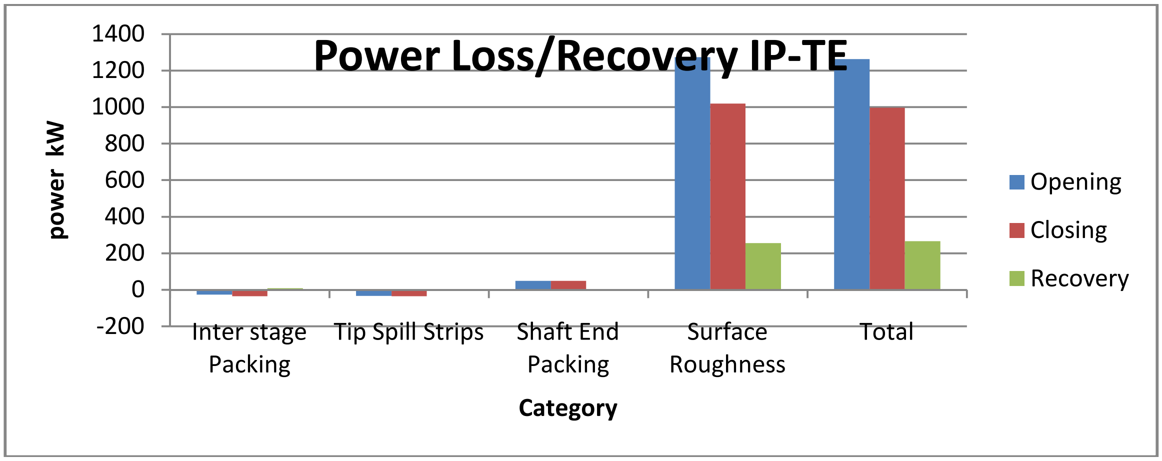

Figure 9 CHANGES IN TOTAL POWER IN IP (TE)

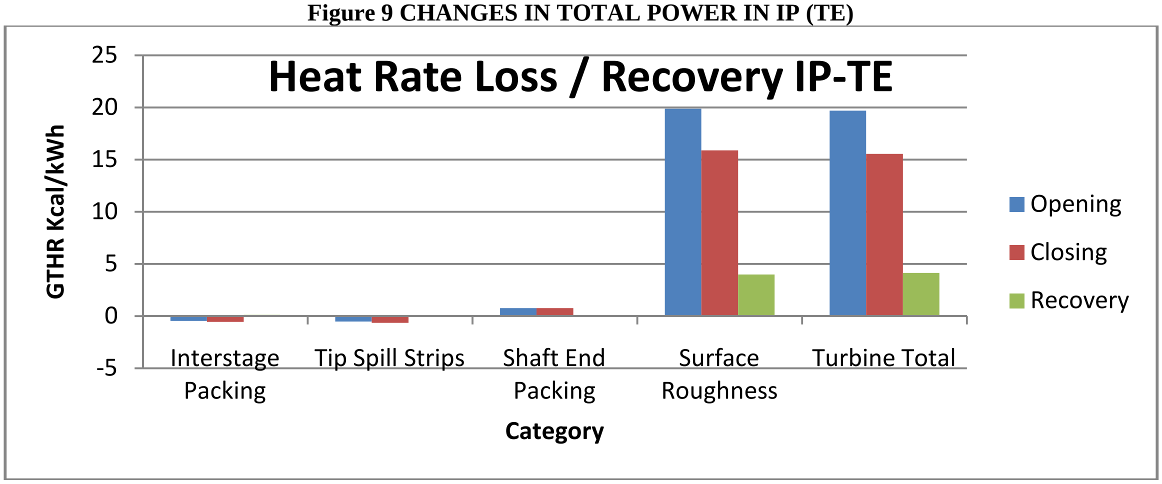

Figure 10 CHANGES IN TOTAL HEAT RATE IN IP (TE)

Table 26 Remaining loss in IP GE Generator after Capital overhauling

Sr.no	Losses	kW	kJ/kWh
1	Interstage Packing	-5.9	-0.09
2	Tip Spill Strips	24.3	0.38
3	Shaft end packing	91.9	1.43
4	Surface roughness	1053.9	16.43
	Total	1164.2	18.15

ISSN: 2277-9655
Impact Factor: 1.852

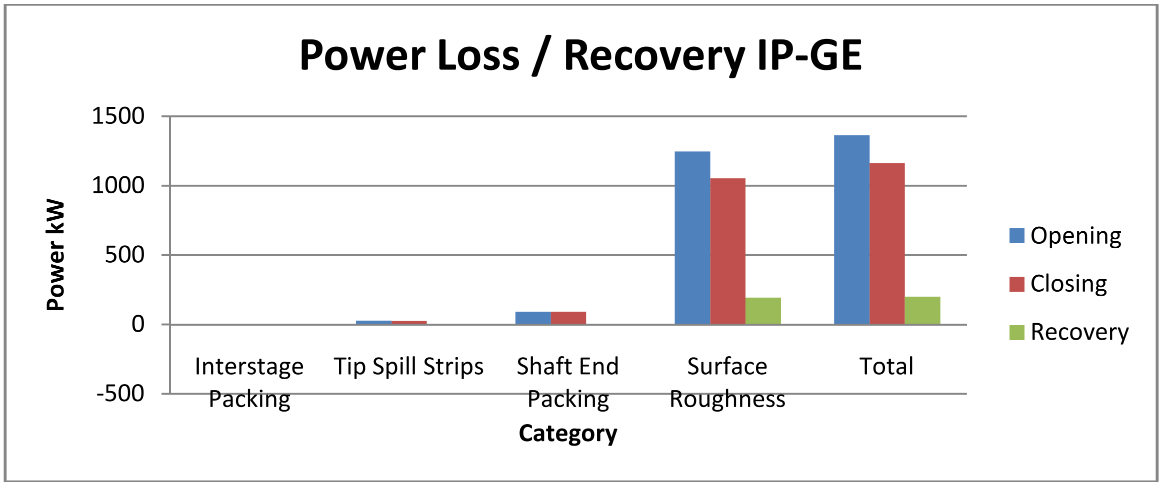

Figure 11. CHANGES IN TOTAL POWER IN IP (GE)

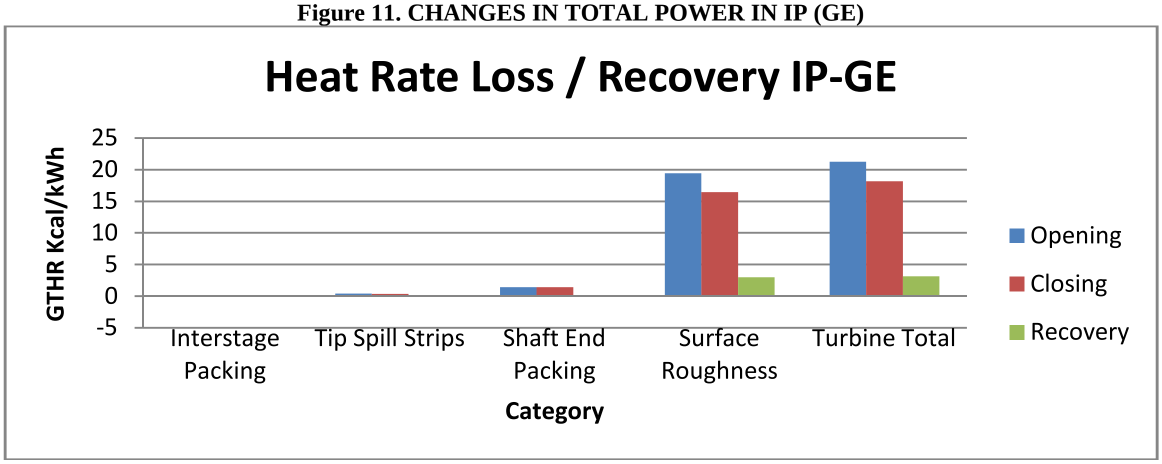

Figure 12. CHANGES IN TOTAL HEAT RATE IN IP (GE)

Conclusion

The steam turbine is one of the major components for power generation. Its performance and reliability is associated with the development of electric power industry. In recent years, demands for effective utilization of energy by reducing fuel consumption and the protection of environment by reducing carbon-dioxide emission are increasing. In order to fulfill these demands, the innovative technologies primarily developed for new plants are increasingly being used to upgrade existing turbines. By applying these technologies; service life of the plant can be extended while achieving significant performance improvement.

This compete discussion on testing procedure, monitoring activities in performance prediction methods has been discussed thoroughly. This data, with its associated results, will establish accurate trends of various performance characteristics. This definitely helps in reduce the turbine deterioration include deposits, solid particle erosion, increased clearances in packing and tip spill strips, and foreign object damages.

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