Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 05, May-2025

Energy-Efficient Motor Retrofit Analysis in a Thermal Power Plant: A Case Study

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Abstract

This paper presents energy-efficient motors' retrofit analysis for low-tension (LT) auxiliary motors at the Lehra Mohabbat Thermal Power Plant (LMTPP), Punjab, India. The study focuses on considering the replacement of aging motors of class IE1 with the class IE4 motors of ABB, in the boiler and clarifier feed pump systems. An audit of motor inventory is conducted to assess their rated powers, load factors, and operational hours. Using nameplate data and catalog values, the analysis has been done to evaluate energy and cost savings and to estimate a simple payback period (SPP). The proposed replacements demonstrate an efficiency improvement between 4–6%, with estimated energy savings of 562,413 kWh/year and associated annual cost savings exceeding ₹39.09 lakh. CO_2 emission reduction of approximately 461 metric tons/year is projected based on national grid emission factors. The results indicate that transition to IE4 motors is technically feasible, economically justifiable, and environmentally beneficial, particularly in high-duty-cycle systems such as thermal power plant auxiliaries.

Keywords

Energy-efficient motors, IE1 motors, IE4 motors, Thermal power plant, Simple payback period (SPP), CO_2 emissions, Motor retrofitting

1. INTRODUCTION

Electric motors account for a significant portion of industrial electricity consumption worldwide, with estimates indicating over 60% of total industrial energy use attributed to motor-driven systems [1]. In India, thermal power plants rely heavily on low-tension (LT) motors for critical auxiliary operations such as feedwater pumping, fuel handling, flue gas management, and chemical dosing. Many of these motors, especially those commissioned during the 1990s, are based on IE1 efficiency standards or are rewound multiple times, resulting in deteriorated efficiency and increased energy losses.

To address these challenges, national and international agencies such as the Bureau of Energy Efficiency (BEE), the Central Electricity Authority (CEA), and the International Electrotechnical Commission (IEC) have advocated the adoption of higher efficiency motor classes (IE2, IE3, and IE4) as per IS 12615 and IEC 60034-30-1 [2, 3]. Among these, IE4-class motors represent the highest efficiency segment currently available for industrial deployment. Replacing legacy motors with IE4 alternatives offers a viable pathway to reduce energy consumption, operational costs, and carbon emissions in industrial applications.

This paper focuses on a real-world case study conducted at the Lehra Mohabbat Thermal Power Plant (LMTPP) in Punjab, India. Stage 1 of the plant, commissioned in 1997–98, has been selected for motor retrofit analysis, specifically targeting the boiler section and clarifier feed pump system. The study aims to quantify the technical, economic, and environmental impact of replacing aging IE1 motors with

ABB-manufactured IE4 motors. Key performance metrics such as annual energy and hence cost savings, CO_2 emission reduction and simple payback period (SPP) were calculated using field data and motor catalog specifications.

The methodology and findings presented in this paper serve as a model framework for similar retrofit interventions in power plants and other energy-intensive sectors.

2. METHODOLOGY

This study employed a structured four-phase methodology to evaluate the energy-saving potential of retrofitting aging IE1 motors with IE4 motors in a thermal power plant environment. The approach combined field data collection, catalog-based motor selection, and economic analysis using the Simple Payback Period (SPP) model.

2.1 Motor Inventory and Data Collection

The first step involved identifying and documenting the LT motors currently installed in the boiler and clarifier feed pump systems of Stage 1 at the Lehra Mohabbat Thermal Power Plant (LMTPP), Punjab. A total of 207 motors were analyzed, comprising of 167 motors in the boiler section and 40 motors in the clarifier feed system. For each motor, the following parameters were recorded:

- Rated power (kW)
- Rated speed (RPM)
- Rated voltage and current
- Duty hours (estimated from operational logs)
- Nameplate efficiency (if available)
- Number of times the rewinding of motors done (where known)

This data was cross-referenced with site maintenance records and operator inputs to ensure accuracy.

2.2 Selection of Motors for Replacement

Replacement motors were selected from the ABB IE4 product range. ABB's IE4 motors are compliant with IS 12615:2018 and IEC 60034-30-1, and offer improved performance over legacy IE1 motors. Selection was based on:

- Power rating equivalence
- Frame size and mounting compatibility (per IEC 60072)
- Operational suitability for continuous duty (S1)
- Environmental protection features (IP55, Class F insulation)

IE4 motor efficiency values were extracted from ABB's FRSM 66 catalog and consolidated technical brochures [4][5].

2.3 Energy and Cost Saving Calculation

The energy savings obtainable after replacing an IE1 motor with an IE4 motor are estimated using the following formula:

Energy Saved (kWh/year) = P × LF × (1/η_old − 1/η_new) × H

Where:

P = Rated Power of motor (kW)

LF = Load factor (0.80 used for estimation)

η_old = Efficiency of existing IE1 motor

η_new = Efficiency of proposed IE4 motor

H = Annual operating hours

The corresponding cost saving are calculated using a fixed electricity tariff of ₹7.00/kWh, the average industrial rate in Punjab.

2.4 Economic Feasibility – Payback Period

To assess the economic viability of the retrofit, the Simple Payback Period (SPP) is calculated as:

SPP (years) = Initial Investment (₹) / Annual Cost Saving (₹/year)

Initial investment included motor procurement costs from ABB's institutional rate list, exclusive of installation costs, which were excluded for conservative estimation.

3. CASE STUDY: LMTPP RETROFIT ANALYSIS

This case study examines the application of energy-efficient motor retrofitting at Lehra Mohabbat Thermal Power Plant (LMTPP), a coal-based facility located in Bathinda, Punjab, India. The focus is on auxiliary motors in Stage 1, which was commissioned in 1997–98.

3.1 Plant Overview

The plant consists of multiple stages, with Stage 1 relying heavily on LT motors to drive boiler fans, feedwater pumps, clarifier systems, and other auxiliary machinery. Over two decades of continuous use and multiple rewinding cycles might have led to significant efficiency degradation.

3.2 Motor Inventory Analysis

The audit covered 207 motors: 167 in the boiler section and 40 in the clarifier feed system. Recorded parameters included:

- Power Rating: 0.75 to 75 kW
- Speed (RPM)
- Load factor (assumed 0.80)
- Operating Hours: 5,000 to 8,000 per year
- Efficiency deviation estimated from nameplate to actual conditions

3.3 IE4 Replacement Strategy

All motors were mapped to ABB's IE4 series motors based on matching kW, frame size, mounting type, and operating conditions. The goal was to maintain a one-to-one replacement to avoid structural or electrical redesign.

3.4 Installation and Integration

ABB IE4 motors were selected for their:

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 05, May-2025

- B3 mounting (foot-mounted compatibility)
- IP55 protection and Class F insulation
- IEC 60072 standard frame sizes

This ensured drop-in installation cost without major modifications.

3.5 Initial Investment Summary

As per ABB's FRSM 66 catalogue, the procurement costs were:

- Boiler Section (167 motors): ₹39.97 lakh
- Clarifier Feed Pump Section (40 motors): ₹20.45 lakh
- Total Investment: ₹60.42 lakh

This investment formed the baseline for evaluating energy savings and payback discussed in the next section.

4. RESULTS AND ANALYSIS

This section presents the quantifiable outcomes of the motor retrofit analysis, focusing on energy savings, cost benefits, and environmental impact.

4.1 Estimation of Energy Savings

Based on motor audit data and efficiency comparisons between existing IE1 and proposed IE4 motors, the annual energy savings are calculated. The total estimated energy saved across the boiler and clarifier feed systems is:

- Total Energy Saved: 562,413 kWh/year

4.2 Cost Savings and Economic Payback

Assuming an electricity tariff of ₹7.00 per kWh, the estimated cost savings are:

- Annual Cost Savings: ₹39.09lakh
- Simple Payback Period (SPP): Ranged from 2.2 to 3.0 years, depending on motor size, runtime, and efficiency differential.

4.3 CO_2 Emission Reduction

Using the Central Electricity Authority (CEA) emission factor of 0.82 kg CO_2/kWh, the carbon emissions avoided through reduced energy use were calculated:

- CO_2 Avoided = 562,413kWh × 0.82 kg CO_2/kWh = 461,179 kg/year (≈ 461 metric tons)

4.4 Maintenance and Reliability Benefits

In addition to energy and cost savings, IE4 motors are expected to reduce maintenance frequency and improve system reliability. Key advantages include:

- Reduced rewinding and breakdowns
- Sealed bearings and better insulation (Class F)
- Improved thermal and mechanical stability

These operational benefits further strengthen the case for retrofit adoption in thermal power plant auxiliaries.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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5. CONCLUSION AND FUTURE WORK

This section concludes the study and outlines directions for future research and plant-wide implementation.

5.1 Conclusion

This study evaluated the technical, economic, and environmental feasibility of retrofitting aging IE1 motors with energy-efficient IE4 motors at Lehra Mohabbat Thermal Power Plant (LMTPP), Punjab. The case study focused on the boiler and clarifier feed pump systems, analyzing a total of 207 motors.

Key outcomes include:

- Estimated energy savings: 562,413 kWh/year
- Annual cost savings: ₹39.09 lakh
- CO_2 emission reduction: 461 metric tons/year
- Payback period: 2.2–3.0 years

These findings affirm that retrofitting with IE4 motors is a viable and impactful energy efficiency strategy.

5.2 Future Work

Although the results are promising, several opportunities for further improvement exist:

- Expand the analysis to cover the entire LT motor inventory, including coal handling and water treatment systems
- Use portable data loggers to capture real-time power, current, and load variations
- Explore the integration of Variable Frequency Drives (VFDs) for load-varying motors
- Consider Life Cycle Cost Analysis (LCCA) to incorporate depreciation and maintenance escalation
- Develop a predictive maintenance framework using thermal sensors and energy meters for IE4 motors

These steps would improve the accuracy of energy audits and support larger-scale motor optimization programs.

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ISSN: 2278-0181
Vol. 14 Issue 05, May-2025

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Appendix A: Motor Inventory Data

Appendix A1: Boiler Section Motor Inventory

Motor Description	**Power (KW)**	**Speed (RPM)**	**Quantity**	**IE1**	**IE4**	**Discount Price(₹) per unit piece**	**Energy Saved Annually(KWH) per unit piece**	**Annual Saving (₹) per unit piece**	**Payback (Yrs)**
				Efficiency					
RAPH Main Drive Motor	11	1450	4	87.60%	93.30%	56125	4861	34025	1.65

Scaner Air Fan (AC)	3.7	2850	2	82.70%	90.50%	20525	2443	17102	1.20
Scaner Air Fan (DC)	3.7	3000	2	82.70%	90.50%	20525	2443	17102	1.20
Air PH Gulde Bearing LOP	0.55	1415/905	8	69.10%	84.10%	9150	899	6296	1.45
APH Support Bearing LOP	0.75	1400/1415	8	72.10%	85.60%	9900	1039	7276	1.36
AH I/lLFlue Gas Damper (GD-1)	0.55	1440	4	69.10%	84.10%	9150	899	6296	1.45
AH O/L Flue Gas Damper (GD-2)	0.55	1440	4	69.10%	84.10%	9150	899	6296	1.45
SH Spray Line Isolating V/20 (S-56)	3.7	2940	2	82.70%	90.50%	20525	2443	17102	1.20
UP Steram ISO V/20 of SH Main Spray (S-62,S61)	1.6	1360	4	77.20%	88.50%	12700	1677	11737	1.08
AH I/L Hot Primary Air Damper (PAD-4)	0.37	1360	4	65.10%	83.50%	7650	794	5555	1.38
AH I/L Cold Primary Air Damper (PAD-3)	0.37	1360	4	65.10%	83.50%	7650	794	5555	1.38
Main Feed Control V/V 100% Up Streem V/V	6.9	1350	4	86.00%	93.30%	32075	3977	27842	1.15
Main Feed Control V/V 100% Up Streem V/V	6.9	1350	4	86.00%	93.30%	32075	3977	27842	1.15

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ISSN: 2278-0181
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Up Steram ISOl Low Load feed Cont. V/V	2.2	2800	2	79.70%	89.10%	13425	1845	12916	1.04
Down stream ISO Low Load Feed Cont. V/V	2.2	2800	2	79.70%	89.10%	13425	1845	12916	1.04
AH O/L Seconday Air Damper (SAD-3)	0.37	1440	4	65.10%	83.50%	7650	794	5555	1.38
Economizer Re-Circus. ISO Lighting V/V (E-9)	1.6	1360	2	77.20%	88.50%	12700	1677	11737	1.08
Economizer Re-Circus. ISO Lighting V/V (E-2)	6.9	1350	2	86.00%	93.30%	32075	3977	27842	1.15
Gundry Come Motor APH	4.0	1360	1	82.70%	91.40%	20900	2917	20419	1.02
MS Line Drain (South) to BD Drain V/V	1.2	1360	2	75.00%	87.60%	11000	1458	10207	1.08
MS Line Drain (North) to BD Drain V/V	1.2	1360	2	75.00%	87.60%	11000	1458	10207	1.08
Main Strem Stop V/V (DC)	9.2	1600	4	86.00%	93.10%	53592	5169	36184	1.48
By Pass V/V to Main Strem Stop V/V	1.2	1360	4	75.00%	87.60%	11000	1458	10207	1.08
Soot Blower Stram Control V/V (D-99)	1.2	1360	2	75.00%	87.60%	11000	1458	10207	1.08

Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
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SH Start Up Vent Isolating V/V (/S-39840)	3.3	1310	4	82.70%	91.40%	20900	2407	16846	1.24
Drum Downcomer of Drain to IBD Regulation V/V IBD-70	1.6	1360	2	77.20%	88.50%	12700	1677	11737	1.08
Drum Downcomer of Drain to IBD Regulation V/V (B-71)	1.2	1360	2	75.00%	87.60%	11000	1458	10207	1.08
Inching V/V on Aux Steam Line to SCAPH	1.2	1360	4	75.00%	87.60%	11000	1458	10207	1.08
APH Wash Pump	45	2960	2	91.70%	95.20%	174754	11431	80018	2.18
Boiler Fill Pump	75	2970	2	92.70%	95.60%	285340	15550	108852	2.62
Hot Well Make Up Pump	15	1460	4	88.70%	94.00%	61632	6041	42289	1.46
Stator Water Make Up Pump	3.7	2850	2	82.70%	90.50%	20525	2443	17102	1.20
LOP of Motor	6.5	1440	8	86.00%	93.20%	32975	3700	25897	1.27
Discharge Dampers (SAD-2)	0.37	1440	4	65.10%	83.50%	7650	794	5555	1.38
LOP of Motor	0.37	1370	12	65.10%	83.50%	7650	794	5555	1.38
O/L Gate Blowers	3.7	2900	6	82.70%	90.50%	20525	2443	17102	1.20
O/L Gate Discharge Dampers (GD-9)	3.7	2800	6	82.70%	90.50%	20525	2443	17102	1.20
I/L Gate Discharge Dampers (GD-7)	3.7	2800	6	82.70%	90.50%	20525	2443	17102	1.20

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LOP of Motor	1.5	1410	8	77.20%	88.50%	12700	1572	11003	1.15
HOP Motor	3.7	2800	8	82.70%	90.50%	20525	2443	17102	1.20
Discharge V/V	7.5	2800	4	86.00%	92.10%	32975	3660	25618	1.29

Appendix A2: Clarifier Feed Pump Motor Inventory

Motor Description	Power (KW)	Speed (RPM)	Quantity	IE1	IE4	Discount Price(₹) per unit piece	Energy Saved Annually (KWH) per unit piece	Annual Saving (₹) per unit piece	Payback (Yrs) per unit piece
				Efficiency					
Sludge Pit Pump Motors	75	1480	2	92.70%	96.00%	252760	17621	123350	2.05
Service water pump Motors	75	1482	3	92.70%	96.00%	252760	17621	123350	2.05
Pretreated Raw water Pump (PWR)	30	1470	3	90.70%	95.00%	117984	9486	66401	1.78
Flash Mixer Motor	11	1400	1	89.80%	93.30%	56125	2912	20381	2.75
Clarifier Bridge Movement Motor	3.7	1430	1	82.70%	91.40%	20900	2698	18888	1.11
Clarifier Bridge Folculator Motor	2.2	920	4	77.70%	87.60%	19225	2027	14192	1.35
Alum Dosing Pump Motor	0.37	1405	2	65.10%	83.50%	7650	794	5555	1.38

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Alum Dosing Pump Motor	1.5	1350	2	77.20%	88.50%	12700	1572	11003	1.15
Alum Dosing Agitator	2.2	710	2	67.90%	80.90%	26600	3299	23092	1.15
Clarifier Blanket Scrapper Motor	0.75	1400	1	72.10%	85.60%	7650	1039	7276	1.05
Sludge Blanket Clarifier Fulculator	0.37	1350	3	65.10%	83.50%	7650	794	5555	1.38
Re-Circulator WTP Pump Motor	0.75	2850	2	72.10%	85.60%	8400	1039	7276	1.15
Roof Exhaust Fan of Tube Axial Fan	0.75	910	8	65.00%	83.90%	11575	1647	11528	1.00
Exhaust Fan ***	0.132	900	4	55.00%	83.90%	8150	524	3667	2.22
Fore Bay Make Up V/v	0.25	1400	1	65.10%	83.50%	7650	536	3753	2.04