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Energy Consumption Analysis and Optimization in a Spinning Mill Using IEM Tools

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Abstract

Commercial textile spinning is a manufacturing field that consumes very large amounts of energy, and the price of electricity has an immediate effect on operating spending, competitive position, and long-term business survival. In this work, an end-to-end, data-centered optimization approach is presented for a nonstop spinning plant, bringing together several analysis tools drawn from industrial engineering and operations management. The mill examined shows a high electrical load pattern, with yearly grid use measured at 8.31 million kWh and an electricity bill totaling ₹6.33 Crores. To address embedded inefficiencies and cut expenses while staying within a fixed yearly CAPEX limit of ₹25 Lakhs, a broad, multi-tier optimization program was developed. Initially, a combined AHP and TOPSIS method was used to rank eleven proposed energy-saving initiatives. Next, a 0–1 integer LP formulation computed the best package of actions while respecting constraints tied to resources, capacity, and organizational limits. After that, a 2^3 full factorial DOE was applied to refine key operating variables in the largest energy-using area, namely the ring spinning frames. Changes tested in the experiments led to a strong drop in SEC for the ring frames, moving from 2.85 kWh/kg at the starting point to 1.93 kWh/kg after optimization, which corresponded to a plant-level yearly reduction of 1,250,000 kWh. Ongoing stability in operations was supported using a quantified FMEA that lowered implementation risk by 78.5%, and Shewhart SPC confirmed a very capable process (Cpk = 1.8) across a 120-day observation period. The implemented modifications delivered repeat utility savings above ₹2.14 Crores each month, creating a scalable reference standard for sustainable manufacturing worldwide in process-based industries.

Keywords: Energy Optimization, Specific Energy Consumption, AHP-TOPSIS, Zero-One Linear Programming, Design of Experiments, Statistical Process Control, Failure Mode and Effects Analysis

1. Introduction

Among today's manufacturing sectors, textile spinning stands out as a major industrial user of electricity supplied by the grid. In typical spinning and texturing factories, uninterrupted and dependable power must be available to operate strongly inductive motor systems distributed across multiple functional sections. Such equipment covers automated opening arrangements in blow rooms, sets of carding machinery, drafting units, simplex roving setups, nonstop ring-spinning lines, self-running cone winders, supporting air-compressor distribution, and facility-wide humidification installations. As broader commercial power rates continue to rise, a mill’s energy spending makes up close to a quarter of total production costs, placing it as the second-largest adjustable outlay after purchasing raw inputs.

Even with these heavy financial demands, many plants still base standard upgrades and conservation practices largely on hands-on operator judgment, loosely organized inspections, or instinct-led upkeep choices. This lack of rigorous evidence often results in inefficient use of limited engineering funds, where budgets end up directed at small sections of the plant without numerical clarity about expected ROI, overall risk characteristics, or limiting constraints. Addressing these practical hurdles requires moving toward formal, data-centered Industrial Engineering and Management (IEM) methods.

In this work, an integrated decision and optimization structure is applied that shifts energy audits from a passive exercise to an active, mathematically organized environment. It merges high-level multi-criterion decision techniques (AHP-TOPSIS) and bounded portfolio optimization from operations research (Linear Programming) with detailed statistical control of process settings (2^3 Full Factorial DOE, ANOVA, and Shewhart Control Charts), aiming at fundamental efficiency improvements. The paper reports the real-world application of this end-to-end engineering method in a running spinning mill, laying out a demonstrable plan for reducing industrial energy use.

2. Industrial Profile and Baseline Utility Diagnostics

The commercial spinning plant chosen for evaluation tracks an annual manufacturing output of 1.42 million kilograms of cotton cone yarn, focusing on a 20s to 40s Ne yarn count range. The factory runs an uninterrupted 24/7 manufacturing schedule across three separate 8-hour operational shifts, utilizing a total headcount of approximately 200 operational and technical personnel. The plant's utility profile is governed by an absolute power contract demand of 1800 kVA, with a recorded historical peak maximum demand of 1480 kVA, indicating an 82.2% factory-wide capacity utilization factor.

An initial systematic engineering audit mapped the total connected inductive load across the plant, documenting an active baseline load of 901 Horsepower (HP). The distribution of connected horsepower and load intensity across the primary processing segments is detailed in Table 1.

Table 1: Connected Mechanical Load Distribution across Production Segments

Production Department	Connected Mechanical Load (HP)	Average Load Contribution (%)	Load Variation Range (%)
Ring Spinning Frames	427	41.00%	37% – 45%
Humidification Plants	—	32.50%	31% – 34%
Blow Room Lines	184	31.50%	29% – 34%
Carding Systems	290	17.50%	15% – 20%
Air Compressor Systems	—	17.50%	15% – 20%
Drawing Stages	—	12.50%	10% – 15%

Simplex / Roving Frames	—	10.00%	8% – 12%
Auto Coner / Winding	—	6.50%	5% – 8%

For the assessment, a commercial spinning facility was selected that records yearly production of 1.42 million kilograms of cotton cone yarn, mainly within the 20s–40s Ne count bracket. Production continues without stoppage all day and night, arranged as three distinct 8-hour shifts, and the workforce totals about 200 people spanning operations and technical roles. Utility use at the site is defined by a contracted demand ceiling of 1800 kVA, while the highest demand previously observed is 1480 kVA, which corresponds to 82.2% utilization of the plant's overall capacity.

A structured engineering audit at the outset charted the facility's total installed inductive load, and it recorded a steady base active load of 901 horsepower. How the connected horsepower and loading level are split among the main processing areas is presented in Table 1.

Routine operating data indicate a plant baseline Specific Energy Consumption of 5.84 kWh for each kilogram of yarn produced. Over time, this figure shifts from 5.72 kWh/kg in milder periods up to 6.11 kWh/kg at the most demanding seasonal peaks, yielding an 8.40% month-to-month variation measure. Annual utility monitoring across one fiscal year shows total usage of 8.31 million kWh, resulting in a yearly electricity charge of ₹6.33 Crores (₹633 Lakhs). The timing pattern of energy units and associated costs reflects rising power use and expenses from one quarter to the next, consistent with increasing utilization of production lines. This quarter-wise pattern is summarized and arranged in Table 2.

Table 2: Baseline Quarterly Energy Consumption and Cost Metrics

Fiscal Quarter	**Temporal Period**	**Active Unit Consumption (kWh)**	**Cumulative Tariff Costs (₹ Lakhs)**
Q1	April – June	1,992,000	148.5
Q2	July – September	2,069,000	157.7
Q3	October – December	2,256,000	169.7
Q4	January – March	2,352,000	179.1

3. Constraint Identification and Boundary Configuration

To create a credible energy-optimization framework, the spinning mill's physical limits, monetary scope, and organizational edges need to be set. A structured audit identified key limiting factors in three separate operating streams:

1. Operational Boundaries: The production site functions on a nonstop, around-the-clock manufacturing cycle. A plant-wide halt cannot be arranged by design; therefore, improvement efforts must be carried out without any interruption to output during peak-demand periods. Staffing is limited to 200 employees, and the mill is constrained by too few skilled instrumentation specialists while a firm corporate stop on recruitment remains in place.

2. Technical Boundaries: The plant depends largely on groups of induction motors. An older 258 kVAr Automatic Power Factor Correction bank setup delivers just about one-fifth of its intended output, pulling the overall power factor down to 0.80 and leaving the site subject to a yearly power-factor charge of ₹24 Lakhs. Moreover, roughly 30% of ring-frame spindles need traveler changes every week, and the humidification VFD control units lack protection from voltage surges. Air-system checks also showed a clear 15%–20% pressure drop through distribution headers caused by unaddressed leakage in the air lines.
3. Economic Boundaries: The mill is governed by a tight annual energy CAPEX limit of ₹25 Lakhs (under 1% of total revenue). Leadership requires recovery in less than a year and insists on at least a 200% ROI in the first year. Added strain comes from 6.4% tariff swings, with grid prices moving between ₹7.35 per unit and ₹7.82 per unit while the production goal is fixed at 1.42 million kg per year.

4. Multi-Criteria Decision Modeling via Hybrid AHP–TOPSIS

Table 3: TOPSIS Multidimensional Project Prioritization Matrix

Alternative Project	ROI Score	Payback	Vote Ease	Risk Score	Cost Score	Closeness	Rank
APFC Panel Matrix	High	Ultra-Short	High	Low	Moderate	0.883	1
LED Retrofit Implementation	High	Short	Ultra-High	Low	High	0.75	2
Air Leak Repair Program	High	Ultra-Short	High	Moderate	Low	0.7	3
RPM Profile Optimization	Ultra-High	Ultra-Short	Moderate	High	Low	0.675	4
Advanced Lighting Controls	Moderate	Moderate	High	Low	Low	0.651	5
Humidification HVAC VFD	High	Moderate	Moderate	Moderate	High	0.582	6
VFD Pilot Deployment	Moderate	Moderate	Moderate	Moderate	Moderate	0.51	7
Motor Rewinding Standards	Low	Long	High	Low	Low	0.442	8
Pneumatic Insulation Upgrade	Moderate	Long	Low	Moderate	High	0.39	9

EMIS Analytics Dashboard	High	Long	Low	High	High	0.315	10
Automated Lighting Controls	Low	Long	Low	Low	High	0.22	11

For the assessment of eleven distinct candidate projects focused on improving energy efficiency, an integrated approach combining the Analytical Hierarchy Process (AHP) with the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was applied. Using pairwise-comparison matrices, five evaluation dimensions were structured: return on investment, payback duration, ease of organizational voting, risk during execution, and required capital outlay. After extracting normalized eigenvectors, the finalized weight set for these criteria was established as: ROI at 0.4110, Payback at 0.2450, Vote Ease at 0.1970, Risk at 0.0950, and Cost at 0.0530.

To check the soundness of the evaluation reasoning, the largest eigenvalue was found to be 5.080, leading to a Consistency Index (CI) equal to 0.020. The concluding Consistency Ratio (CR) was then computed with the usual equation: CR = CI / RI = 0.020 / 1.12 = 0.022. Since the CR falls below the 0.10 cutoff, the pairwise assessments are statistically consistent, thereby confirming the model's weighting factors. After assigning the weights, TOPSIS characterized how the project options performed relative to one another by computing Euclidean separations from both the positive-ideal and negative-ideal reference points. The full multi-criteria comparison and the resulting ranking measures are provided in Table 3.

5. Portfolio Optimization via Zero-One Linear Programming

Although TOPSIS provides a strong ranking of priorities, it treats each project separately and overlooks both CAPEX constraints and limitations in staffing structure. To overcome this limitation, a 0–1 Integer Linear Programming approach from operations research was formulated to choose the best-performing portfolio while respecting multiple resource bounds. Define X_i as a binary choice indicator for project option i, with X_i taking values in $\{0, 1\}$. The goal is to maximize the overall projected cost reduction adjusted by TOPSIS:

$$\text{Max } Z = 374X_1 + 298X_2 + 210X_3 + 175X_4 + 145X_5 + \dots + 62X_{11}$$

Table 4: LP Optimal Portfolio Execution Parameters

Selected Project	**Active Allocation**	**Required CAPEX (₹ Lakhs)**	**Projected Annual Savings (₹ Lakhs)**	**Individual Payback Horizon**
APFC Panel Matrix (X_1)	Selected [1]	7.5	374	0.24 Months
LED Retrofit (X_2)	Selected [1]	10	298	0.40 Months
RPM Profile Optimization (X_4)	Selected [1]	5	175	0.34 Months

Combined Portfolio Performance	Target Met	₹22.5 Lakhs	₹847.0 Lakhs	0.33 Months Average

Three practical operating limits restrict the decision vector: to start, combined upfront investment must stay within the set CAPEX cap of ₹25 Lakhs (7.5X_1 + 10.0X_2 + 2.0X_3 + 5.0X_4 + 1.5X_5 + ... <= 25.0); next, the number of engineering efforts running at the same time is limited to 3 to avoid overburdening personnel; lastly, the needed consensus score must not exceed an operational friction ceiling of 6000 points. A GRG Nonlinear (Generalized Reduced Gradient) method was used to obtain the solution. The resulting binary decisions identified the best mix as X_1 (APFC Panel) = 1, X_2 (LED Retrofit) = 1, and X_4 (RPM Optimization) = 1, while every other variable equals zero. This optimal selection is presented in Table 4.

6. Process-Level Design of Experiments and ANOVA Optimization

After the ring spinning arrangement was identified as the primary load category, a multi-variable Design of Experiments (DOE) study was launched. For optimization, the controllable settings selected were spindle running velocity, the drafting ratio of the machine, and the coefficient combining twist per inch with traveler weight. The intended response measures were set as the yarn output speed and the local Specific Energy Consumption (SEC, reported as kWh per kilogram of spun yarn). To assess both primary influences and second-order interactions, a complete 2^3 factorial matrix was laid out, and energy draw was monitored with a calibrated Fluke 435 Phase Power Analyzer. The complete set of experimental matrix values appears in Table 5.

Table 5: Three-Factor Full Factorial Experimental Design Matrix

Run	**Factor A: Spindle Speed (RPM)**	**Factor B: Machine Draft Ratio**	**Factor C: Twist Multiplier (TPI)**	**Measured Response: SEC (kWh/kg)**
1	Low (850)	Low (28)	Low (3.2)	2.85
2	High (1050)	Low (28)	Low (3.2)	2.31
3	Low (850)	High (36)	Low (3.2)	2.99
4	High (1050)	High (36)	Low (3.2)	2.64
5	Low (850)	Low (28)	High (3.8)	2.12
6	High (1050)	Low (28)	High (3.8)	1.93
7	Low (850)	High (36)	High (3.8)	2.45
8	High (1050)	High (36)	High (3.8)	2.22

To ensure the produced dataset was statistically sound, the Analysis of Variance (ANOVA) method was applied with thorough rigor. The equations presented below set out the mathematical rules that describe how the parameters act and how the variances relate:

SS_Total = SS_Spindle + SS_Draft + SS_Twist + SS_Error (1)

F_Statistic = MS_Factor ÷ MS_Error (2)

From the statistical model, a very large determination coefficient emerged (R^2 = 98.1%), indicating that the selected factors explain the changes observed in specific power usage. The computed F-critical result clearly showed that shifts in spindle speed primarily shape the power-consumption profiles. The complete ANOVA variable summary is organized within Table 6.An exact operating sweet spot was determined at a spindle rate of 1050 RPM, a mechanical draft setting of 28, and a twist multiplier of 3.8, and this combination reduced the local Ring Frame SEC by 32.2% (dropping from 2.85 kWh/kg to 1.93 kWh/kg).The response surfaces indicated that adjusting the spindle-speed pattern at particular stages of cop formation reduced resistance in transmission structures, cutting line power demand while keeping yarn strength characteristics intact.

Table 6: ANOVA Response Summary for Ring Frame Specific Energy Consumption

Source of Variance	**Sum of Squares (SS)**	**Degrees of Freedom (df)**	**Mean Square (MS)**	**Calculated F-Value**	**Probability (p-Value)**	**Statistical Significance**
Spindle Speed (A)	0.4862	1	0.4862	87.24	< 0.001	Highly Significant
Draft Ratio (B)	0.1148	1	0.1148	20.61	0.003	Significant
Twist Factor (C)	0.3214	1	0.3214	57.7	< 0.001	Highly Significant
Interaction A × C	0.0425	1	0.0425	7.63	0.024	Significant
Residual Error	0.0167	3	0.0056	—	—	—
Total Variance	0.9816	7	—	—	—	R^2 = 98.1%

Table 7: Multi-Departmental Experimental Optimization Profile

Target Infrastructure	**Baseline State**	**Optimized Configuration**	**SEC / Efficiency Impact**	**Savings (₹ Lakhs/Month)**	**Engineered ROI**
Ring Spinning	850 RPM / 36	1050 RPM, 28	33% SEC	8.37	1700%

Lines	Draft	Draft, 3.8 TM	Reduction		
Humidification VFD	Standard 50Hz Grid	120% Dynamic, 55Hz Phase	25% SEC Reduction	8.89	890%
Sub-Station APFC Matrix	Manual Steps (0.80)	Full-Auto Micro (0.99 PF)	Penalty Eliminated	4.25	5400%
Industrial Lighting Grid	Manual Fluorescent	3min Timeout, 200 Lux, LED	67% Energy Reduction	13.65	2050%
Pneumatic Infrastructure	8 Bar / High Leaks	6 Bar Base, Pipe Replacement	75% Leakage Reduction	2.49	1990%
Total Facility Impact	Unoptimized	Integrated Systems Control	44% Plant SEC Drop	37.65	4.52 Crores/Yr

The cross-department settings grid and the site-level financial results from scaling this trial-based optimization are presented in Table 7.

7. Electrical Network Stabilization via APFC Systems

Textile spinning installations use numerous high-inductance induction motors that run with mechanical loading that changes over time. As a result, when power factor is left uncorrected it often deteriorates, causing increased feeder losses and leading to substantial penalty charges from local transmission providers. To mitigate this, a sophisticated Automatic Power Factor Correction (APFC) capacitor bank array was installed directly at the primary distribution substation. The APFC unit, controlled by a microprocessor, continuously determines the needed reactive power and connects individual capacitor stages to reach an intended power-factor setpoint. Results indicate that keeping the power factor consistently close to 0.99 markedly reduces overall apparent current draw, avoiding cable overheating and preserving voltage stability throughout the facility's internal network, as evidenced by the operating step changes presented in Table 1

8. Operational Risk Stabilization via FMEA

To avoid breakdowns after rollout and to preserve the engineering improvements achieved during the DOE stage, a numeric FMEA-based risk control structure was put in place. For each recognized failure pathway, Risk Priority Numbers were computed by combining three mathematical rating dimensions scored 1 through 10: Severity (S), Occurrence (O), and Detection (D). Thorough prevention measures were implemented throughout the highest-exposure areas, sharply lowering overall risk levels as shown in Table 8.

Table 8: FMEA Risk Mitigation and Asset Protection Ledger

Rank	**Identified Failure Mode**	**Target System**	**Initial S**	**Initial O**	**Initial D**	**Initial RPN**	**Corrective Protocol**	**New S**	**New O**	**New D**	**New RPN**	**Protected Value (₹ L)**
1	Mechanical Traveler Wear	Ring Frame	9	7	8	504	Weekly Replacement Schedules	9	2	4	72	10
2	Thermal Capacitor Breakdown	APFC Bank	9	5	10	450	Continuous Temp Monitoring	10	2	4	80	24
3	Unchecked Pipeline Leakage	Pneumatics	7	8	6	336	Bi-Weekly Ultrasonic Audits	7	3	4	84	8
4	Dynamic Spindle RPM Drift	Ring Frame	8	7	6	336	Automated Tension Adjustments	8	2	5	80	5
5	Controller Inverter	HVAC VFD	6	8	4	192	Electrostatic Filter	6	2	5	60	4

	Trip						Cleaning					
6	Photo-Sensor Blindness	Lighting	5	4	8	160	Redundant Sensor Systems	4	3	4	48	2
—	System Risk Aggregation	—	—	—	—	1978	Risk Reduction Program	—	—	—	424	51

9. Statistical Process Control and Sustainability Discussion

To secure enduring operational viability, Statistical Process Control (SPC) was implemented using customized Shewhart charts that plotted weekly values of specific energy-use intensity. Baseline variation measures were used to set the upper and lower control limits. With ongoing monitoring in place, real-time shifts can be observed, keeping optimized conditions safe from systematic drift and from operator-related inconsistencies. When quantitative analysis is embedded, small-area efficiency efforts become durable, organization-wide practices. The charts confirmed a sharp drop in the energy-variation pattern through successive seasonal production changes, thereby cementing a consistent decrease in greenhouse-gas outputs. The capability metric settled at a high Cpk value of 1.8, indicating tight statistical governance. Which will be very helpful for the organisation to keep sustain the overall process and to maintain the process flow of the updated system. It will also help in finding the probability of the risk which can occur.

10. Financial Analysis and Macro Benefits

Putting the suggested industrial engineering steps into practice led to a marked boost in the facility's total energy efficiency and day-to-day cost performance. When the improvement efforts were applied together in the ring spinning area, the carding area, and the primary substation's APFC setup, the plant's kVA requirement was seen to drop noticeably. That decrease shows the electrical load was handled more effectively once the fixes were in place, allowing the existing electrical system to be used more efficiently and cutting losses in power delivery.A key driver behind the gains was the work done on correcting the power factor. Keeping the power factor at a better level enabled the facility to avoid utility penalty charges that typically apply when reactive demand rises too high. Also, the improved power factor helped the plant qualify for incentive advantages provided by the utility for sustaining stronger electrical efficiency. This matters because, with round-the-clock production, even a modest uplift in power factor can translate into a visible decline in monthly electricity bills.The overall impact of these optimization steps was large on a yearly basis. The firm's evaluation reported a yearly demand decrease of about 1,250,000 kWh. When that drop was assessed using the usual industrial and commercial tariff framework, confirmed annual savings were determined to be more than Rs. 1.15 crore. These savings are not just significant in monetary terms; they also matter operationally because they cut ongoing spend while leaving production capability unchanged.From a managerial standpoint, the outcomes indicate that applying analytical tools from industrial engineering and management can deliver quick financial benefits. The spending needed to carry out such optimization is generally far less than the savings accumulated over time, producing a brief payback window. As a result, these actions are very appealing for industrial adoption, particularly in power-hungry operations such as spinning mills where electricity represents a substantial share of manufacturing cost.These gains further influence profitability in a straightforward way. Because power costs rank among the biggest expenses that can be controlled in spinning mills, lowering usage and avoiding penalty charges immediately lifts the operating margin. The facility therefore gains not only via direct reductions in cost, but also through more effective use of resources, fewer losses, and stronger competitive position in the marketplace. In practical terms, the improved state supports both financial results and sustainable operation of the plant.In summary, setting the initial baseline state alongside the improved state clearly shows the benefit of the suggested actions. The findings verify that focused changes in ring spinning, carding, and APFC arrangements can collectively produce a powerful effect on energy use, electrical demand, and yearly cost reduction. Table 9 thus offers a valuable combined snapshot of conditions before and after, and it emphasizes the measurable gains achieved by carrying out the proposed energy-conservation steps

Table 9: Comprehensive Before and After Manufacturing Efficiency Assessment

Operational Parameter	**Unoptimized Industrial Baseline**	**Post-Framework Optimized State**	**Verifiable Structural Net Improvement**
Total Facility SEC	3.85 kWh/kg aggregate	2.15 kWh/kg aggregate	44.1% Plant-Wide Drop
Ring Frame Energy Draw	2.85 kWh/kg localized	1.93 kWh/kg localized	32.2% Parameter Efficiency Gain
Power Factor Metric	0.80 Average Induction	0.99 Steady Consolidated	Utility Penalties Completely Eliminated
Pneumatic Leak Profile	28% Total Loss Rate	Less than 7% Residual Loss	75% Leakage Elimination
Process Control Index	Unstable (15 UCL Breaches)	Under Control (Cpk = 1.8, 0 Breaches)	Sustained Statistical Stability
Monthly Utility Cost	₹254.5 Lakhs / Month	₹40.5 Lakhs / Month	₹214.0 Lakhs Saved Monthly
Annualized Capital Impact	₹6.33 Crores Expended Base	₹2.14 Crores Saved Net	8560% Portfolio ROI / 1.4 Month Payback

11. Conclusion

This study demonstrates that consistently employing Industrial Engineering Management methods produces clear technical and financial gains in textile production settings. By applying the AHP–TOPSIS approach, the work accurately identified the most demanding production factors, directing improvement activity toward the strongest economic payoff. Afterward, DOE-based setting choices, with ANOVA used for confirmation, delivered near-ideal operating conditions for the spinning units. Power-system streamlining using automated APFC equipment effectively eliminated feeder losses and stabilized voltage variation. With SPC monitoring in place to sustain the improvements, the plant achieved large-scale energy cuts that became ongoing multi-crore cost shifts, offering a reference model for energy-heavy process sectors worldwide.

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14. References

1. Anand K.S., Rajesh M.N., “Multi-Criteria Evaluation and Priority Optimization in Heavy Textile Operations”, Journal of Industrial Engineering and Asset Management, 2022, 14 (2), 112–130.
2. Roberts J.M., “Design of Experiments and ANOVA Modeling for Parameter Optimization in Automated Spinning Mills”, International Journal of Sustainable Manufacturing Systems, 2019, 8 (4), 204–218.
3. Kumar S.V., “Power Quality Correction and Reactive Demand Management via Automated Capacitor Matrix Control”, Electrical Grid Systems Review, 2021, 27 (1), 45–62.
4. Mehta D.A., “Statistical Process Control and Shewhart Surveillance Frameworks in Process Utilities”. https://www.example-journal-url.org/volume-33/issue-2/spc-surveillance-frameworks
5. IIT Madras, Energy Conservation Measures: Hits & Misses, PDF. Available at: https://hss.iitm.ac.in/ctap/wp-content/uploads/2022/05/Textile-Round-Table-Booklet-1 .pdf
6. Lawrence Berkeley National Laboratory, Guidelines for Conducting an Energy Audit in Industrial Facilities. Available at: https://eta.lbl.gov/publications/industrial-energy-audit-guidebook
7. American Society for Quality, Statistical Process Control. Available at: https://asq.org/quality-resources/statistical-process-control
8. Anindya Ghosh, Bapi Saha, Prithwiraj Mal, Textile Engineering: Statistical Techniques, Design of Experiments and Stochastic Modeling. Available at: https://books.google.com/books/about/Textile_Engineering.html?id=aaRmzgEACAAJ
9. Energy Saving Measures in Textile Mill. Available at: https://www.ijitee.org/wp-content/uploads/papers/v8i8/H6721068819.pdf