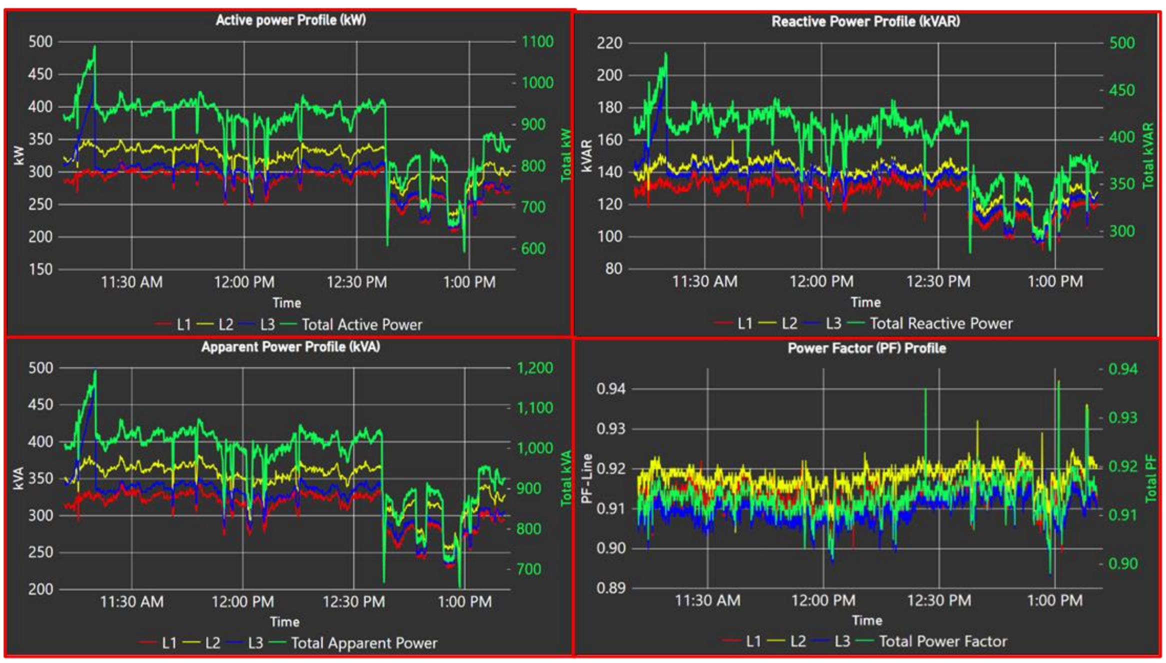
REPORT ON ENERGY AUDIT

FOR

IRIS FABRIC LIMITED.

Zirani Bazar, Kashimpur, Joydebpur, Gazipur



Conducted by

Total Quality. Assured.

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Preface

ITS Labtest Bangladesh Ltd. assessment has successfully identified and evaluated various opportunities for energy conservation and waste minimization. However, due to time limitations during the site visit, the recommendations provided in this report may lack detailed engineering and financial analysis. Therefore, in cases where substantial investments and complex engineering designs are involved, seeking the assistance of specialized consulting engineering firms or experts is strongly advised. Taking appropriate action based on the recommendations can lead to substantial energy savings and reduced waste, benefiting both the environment and the client's operational efficiency.

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Energy Audit Team

ITS Labtest Bangladesh Ltd. experienced team, consisting of a Certified Energy Auditor (CEA), Energy Consultant, and Field Assessors, conducted this Energy Audit. They diligently contributed their time and expertise to thoroughly assess energy consumption and identify areas for optimization. Their collective efforts and dedication were instrumental in thoroughly evaluating energy consumption patterns and identifying opportunities for optimization. The team's expertise and meticulous approach during site visits ensured accurate data collection. The findings and recommendations presented are a result of their comprehensive analysis, tailored to suit the client's specific needs. ITS Labtest Bangladesh Ltd. is committed to delivering top-notch energy auditing services, and our experienced team played a pivotal role in ensuring the accuracy and reliability of the audit results. The audit team consisted of the following members:

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Foreword

IRIS FABRIC LIMITED engaged ITS Labtest Bangladesh Ltd. to perform an Energy Audit at their premises, which took place on 15 November 2023 to 21 November 2023. This certification affirms that the audit adhered to both National and international energy audit guidelines, ensuring a standardized and comprehensive assessment.

The audit team meticulously ensured the correctness of the report, employing modern equipment during on-site measurements to maintain accuracy. Established engineering calculating methodologies were utilized to calculate results, enhancing the reliability of the findings.

The primary objective of the audit was to assist IRIS FABRIC LIMITED in identifying energy consumption patterns and potential areas for improvement. The report contains valuable suggestions to enhance energy efficiency, and ITS Labtest Bangladesh Ltd. expects the management to consider implementing these recommendations.

The successful implementation of the report's suggestions could lead to substantial energy savings, cost reduction, and a positive environmental impact. ITS Labtest Bangladesh Ltd. remains hopeful that the management of IRIS FABRIC LIMITED will take proactive steps to improve energy efficiency and reduce their overall energy consumption based on the energy audit's results.

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Acknowledgement

ITS Labtest Bangladesh Ltd. expresses sincere gratitude to the Management of IRIS FABRIC LIMITED for granting the opportunity to conduct the Energy Audit. Their invaluable support and cooperation made the study possible. We extend our deepest appreciation to all individuals who assisted in data collection and report completion. The collaboration of plant Management personnel, compliance & maintenance personnel, and staff played a crucial role in the successful completion of the Audit. Their help, provision of information, and permission to use necessary equipment and materials were instrumental in the audit's accomplishment.

Engr.Md.Yousuf Ali
Lead Engineer (Sustainability)
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Acronyms And Synonyms

Energy Audit: An energy audit is a comprehensive assessment of energy consumption and efficiency within a building, facility, or process. Its primary goal is to identify opportunities for reducing energy usage, improving energy efficiency, and ultimately cutting down energy costs. Energy audits are commonly conducted in residential, commercial, industrial, and institutional settings to help identify areas where energy is being wasted and to recommend strategies for optimization.

CO2 emission: CO2 emission refers to the release of carbon dioxide gas into the atmosphere, primarily as a result of human activities such as burning fossil fuels (coal, oil, and natural gas), deforestation, and industrial processes. These emissions contribute to the greenhouse effect, which leads to global warming and climate change. Efforts to reduce CO2 emissions are crucial for mitigating the impacts of climate change and promoting environmental sustainability.

HHV (Higher Heating Value): The Higher Heating Value, also known as gross heating value or gross calorific value, represents the total amount of heat released when a given quantity of fuel is burned completely and the products of combustion are cooled down to the initial temperature. HHV takes into account the heat released by the combustion of the fuel itself as well as the latent heat of vaporization of any water vapor present in the exhaust gases. This means that HHV considers the energy released when the water vapor in the combustion products condenses back into liquid water. HHV is typically higher than LHV because it includes the energy of the water vapor's phase change.

LHV (Lower Heating Value): The Lower Heating Value, also known as net heating value or net calorific value, is the amount of heat released when a given quantity of fuel is burned completely and the products of combustion are not allowed to undergo any phase changes. This means that LHV assumes that the water vapor formed during combustion remains in the gaseous state, and no energy is recovered from its condensation. LHV is generally lower than HHV because it does not include the latent heat of vaporization of water vapor.

Absorption chiller: An absorption chiller is a cooling device that uses heat energy to drive a refrigeration cycle, producing cooling effects without the need for traditional electrically-driven compressors. It's particularly useful in situations where waste heat or other heat sources are available, making it energy-efficient and environmentally friendly.

payback period: The payback period refers to the length of time it takes for an investment to generate enough net cash flows to recover its initial cost. It's a financial metric used to assess the time required for an investment to become financially beneficial by offsetting its upfront expenses with the income or savings it generates over time. Shorter payback periods are generally preferred as they indicate quicker returns on investment.

Executive Summary

1.0: OVERVIEW OF THE INDUSTRY

IRIS Fabric Limited, originating as Mark Style in 1997 and transitioning to manufacturing in 2003 under the IRIS Group, is a leading name in Bangladesh's textile industry. Specializing in knit-based textiles, it offers comprehensive services including knitting, dyeing, washing, sewing, and more. With a strong client base including H&M and Kmart, IRIS Fabric, established in 2004, excels in producing knit garments and lingerie from its facility in Dhaka, showcasing commitment to technology, quality, and eco-friendly practices.

2.0: ENERGY INFRASTRUCTURE, CONSUMPTION AND PRODUCTION PATTERN

IRIS Fabric Limited's energy management system effectively combines a 1500MW primary natural gas generator, a 1030KW standby unit, a 4 MW grid transformer, a 145 KW solar PV installation, and diverse diesel generators (770 KVA, 220 KW, 176 KW, 1660 KW) for electrical needs. Additionally, it includes a 14 Ton/Hr and a 10.88 Ton/Hr natural gas-fired boiler, and a 1.198 Ton/hr exhaust gas boiler for thermal energy. In 2022, their energy use varied: January saw high efficiency with 20,996,750 MJ for 4,841,794 pieces, while September was less efficient with 23,893,804 MJ for only 2,854,492 pieces. December ended with 17,978,158 MJ for 3,780,714 pieces, indicating fluctuating efficiency in energy and resource management.

3.0: ENERGY EFFICIENCY STATUS

3.1: Existing energy efficiency and conservation status:

IRIS FABRIC LIMITED has implemented several highly effective energy efficiency measures, demonstrating their commitment to sustainability and resource optimization:

1. **Exhaust Gas Boiler (EGB) Utilization**: The facility successfully harnesses waste heat from natural gas generators using a 1.8 Ton/hr EGB. This innovative approach transforms potential waste into a valuable source of thermal energy, enhancing overall energy efficiency.
2. **Condensate Recovery System**: Emphasizing condensate recovery, IRIS efficiently recycles condensed steam back to the feed pump. This process not only conserves water but also reuses heat energy, leading to considerable energy savings.
3. **Economizer Installation**: Economizers in the steam generation system recover heat from flue gas, preheating feedwater before it enters the boiler. This significantly boosts the system's energy efficiency, reducing fuel consumption and operational costs.

4. **Maximizing Energy Efficiency in Garment Ironing with G Trap Technology:**

   The "G trap" system significantly enhances energy efficiency in garment ironing by minimizing steam wastage and ensuring effective steam delivery to the fabric. This innovation not only reduces energy consumption but also supports sustainability and cost savings in garment production.

5. **Advanced Water Treatment and Softening**: The comprehensive water treatment process, coupled with a softener plant, ensures high-quality water for steam generation. This prevents scale buildup in boilers, maintaining system efficiency.

6. **Effective Insulation Practices**: With robust insulation throughout the steam generation system, the facility minimizes heat loss, maintaining optimal temperatures and high energy efficiency. Plans to insulate remaining small valves and flanges will further enhance this efficiency.

7. **TDS-Based Blowdown System**: The innovative Total Dissolved Solids (TDS)-based blowdown system effectively manages boiler water impurities, minimizing water and energy wastage.

8. **Boiler Feedback Control System**: This system ensures the management of boiler parameters for low energy consumption and safe, reliable operation.

9. **Technological Efficiency Confirmation**: An energy audit confirmed that the machinery operates within an acceptable energy consumption range, indicating efficient current operational practices.

3.1: Potential energy efficiency and conservation measure:

Having already embraced sustainable energy strategies with successful implementations, IRIS FABRIC LIMITEDis well-positioned for further advancements in energy conservation. The audit team has pinpointed additional opportunities to build upon these initiatives. These forthcoming recommendations are systematically categorized into short-term, medium-term, and long-term measures based on their payback periods.

Short-term measures, characterized by a payback period of less than one year, are quick to implement and yield immediate results.

Medium-term measures, with a payback period of 1 to 3 years, involve more substantial changes and provide significant benefits over a moderate timeframe.

long-term measures, which have a payback period of more than 3 years, are designed for sustained energy efficiency and long-term cost savings.

The table below summarizes these recommendations, outlining a comprehensive strategy for enhancing the factory's energy conservation efforts across various time horizons.

Table: Potential Energy efficiency and Conservation Measures

Serial No	Energy Efficiency/Conservation Measures (EE&CM)	Annual Energy Savings			Energy (GJ/Yr)	Energy cost savings/Yr.	Investment (BDT)	Payback Period, (Year)	Estimated all GHGs (tonnes CO2e) reduction
		Electricity (KWh)	Natural Gas (Cubic Meter)	Diesel (Kg)					
Short Term ECMs (Pay back period less than one year)									
1	Energy Saving (Conservation) by air-fuel ratio adjustment of 14 To/hr Boiler.(Boiler-1)	--	88448	--	3370.68	2307621	50000	0.02	166.9
2	Energy and Cost Savings by Steam Distribution Lines Insulation Improvement	--	86439	--	3294.10	2255192	1500000	0.67	163.1
3	Energy Saving (Efficiency) by replacing existing non condensing economizer to condensing economizer. (all NG fired Boiler-1 and Boiler-2))	--	657800	--	25068.11	17162011	7000000	0.41	1241.1
Medium Term ECMs (Pay back period less than or equal three year)									
4	Potential energy saving by hot water module 6 m3/hr or absorption chiller 63 RT (using a natural gas engine's jacket water circuit)	--	147470	--	5619.93	3847489	11000000	2.86	278.24
Long Term ECMs (Pay back period greater than three year)									
Total		--	980157.64	--	37352.83	25572312.72	19550000.00	0.76	1849.35
Proposed ECM									
5	Energy and Cost Saving by Installing 100 KW Solar PV Net Metering System at Factory Roof-top	126970	--	--	457.09	1269700	4800000	3.78	85.0699

Energy Performance Evaluation

SECTION-1
General information

1.1: IRIS FABRIC LIMITED- A CONCISE OVERVIEW

IRIS FABRIC LIMITED, a prominent name in Bangladesh's textile industry, began its journey in 1997 as Mark Style, a European-focused buying consultancy. Transitioning into manufacturing in 2003 under the IRIS Group, it has since emerged as a leading knit-based textile manufacturer. Known for its comprehensive and vertically integrated operations, IRIS excels in knitting, dyeing, washing, sewing, jacquard, embroidery, and printing, complemented by advanced lab facilities.

The company's reputation is bolstered by its association with renowned global brands like H&M, Next, Lindex, and Kmart, reflecting its commitment to quality and efficiency. With a strategic base in Dhaka and multiple manufacturing units nearby, IRIS efficiently manages a responsive supply chain, vital in meeting demanding deadlines.

IRIS FABRIC, established in 2004, has become a key player in the readymade garment sector, specializing in knit garments and lingerie. Its production facility in Zirani Bazar, Kashimpur, Gazipur, Dhaka, embodies the company's dedication to technological advancement and quality. The impressive roster of clients serves as a testament to IRIS's adherence to eco-friendly practices, quality management, and manufacturing excellence, setting a high standard in the textile manufacturing industry.

1.2: THE PRESENT POWER LANDSCAPE OF IRIS FABIRC LIMITED

IRIS FABRIC LIMITED has developed an advanced energy management system that exemplifies the efficient and sustainable use of resources:

Electrical Energy Infrastructure:

1. **Natural Gas Generators**: The electrical backbone consists of two Caterpillar natural gas-fired generators (1500MW and 1030KW), with the 1030KW unit serving as a standby. This setup ensures reliable power, particularly during grid failures or low gas pressure periods.
2. **Grid Supply**: Complementing the generators, the facility taps into grid electricity through a 33/11 KV transformer (4 MW capacity, 3 MW sanctioned load). Distribution is managed via 2.5 MW and 1 MW 11/.415 KV substations, providing a parallel power source.

3. **Rooftop Solar PV System**: A strategic 145 KW rooftop solar PV system reduces reliance on non-renewable energy, aligning with global renewable energy efforts.
4. **Diesel Generators**: As a secondary backup, two diesel-fired Caterpillar generators (770 KVA each, plus additional units of 220 KW, 176 KW, and 1660 KW) ensure continuous operation during power interruptions or low natural gas supply.

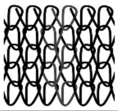
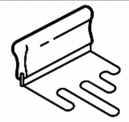
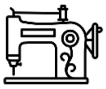
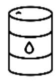
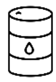
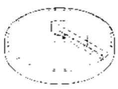
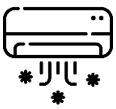
Thermal Energy Infrastructure:

1. **Natural Gas-Fired Boilers**: Key to the thermal energy needs are two natural gas-fired boilers (14 Ton/Hr and 10.88 Ton/Hr), with the latter serving as a standby steam source.
2. **Exhaust Gas Boiler (EGB)**: A 1.198 Ton/hr EGB ingeniously captures waste heat from the natural gas generator, converting it into a valuable thermal energy resource.

This energy infrastructure at IRIS Fabrics Limited represents a harmonious integration of efficiency, environmental stewardship, and operational resilience, reflecting a forward-thinking approach in modern energy management.

1.3 : A SUMMARIZED PORTRAIT OF PROCESS AND ASSOCIATED ENERGY

IRIS FABRIC LIMITED'S production process is an intricate blend of technology and sustainability. Here's a summarized portrait of their key processes and associated energy use:
Knitting: Fabric creation using electricity-powered machines.
Dyeing & Finishing: Color application and fabric treatment, utilizing steam (generated by gas) and electricity.
Printing: Design printing on fabric, relying on electricity, with water usage for processing and cleaning.
Cut to Sewing: Precision cutting and stitching of garments, powered by electricity.
Boiler: Steam generation for various processes, using gas and electricity.
Generator: Backup power provision, primarily using gas and diesel.
Air Compressor: Supporting machinery with compressed air, powered by electricity.
Vehicles: Material and product transportation, fueled by diesel/gasoline.
Office Building and Dining: Administrative and welfare functions, dependent on electricity.
ETP & WTP: Waste and water treatment for sustainability, using electricity.
HVAC: Climate control in facilities, powered by electricity.

		Applicable	Electricity	GAS NG/LPG/CNG	Steam	Diesel/ Gasoline
Knitting		Yes		--	--	--
Dyeing & Finishing		Yes				--
Printing		Yes		--	--	--
Cut to sewing		Yes		--		--
Boiler		Yes			--	--
Generator		Yes			--	
Air compressor		Yes		--	--	--
Vehicles		Yes	--		--	
Office building and dining		Yes			--	--
ETP & WTP		Yes		--	--	--
HVAC		Yes		--	--	--

1.4: ENERGY USE ANALYSIS AND BENCHMARKING (BASELINE YEAR-2022)

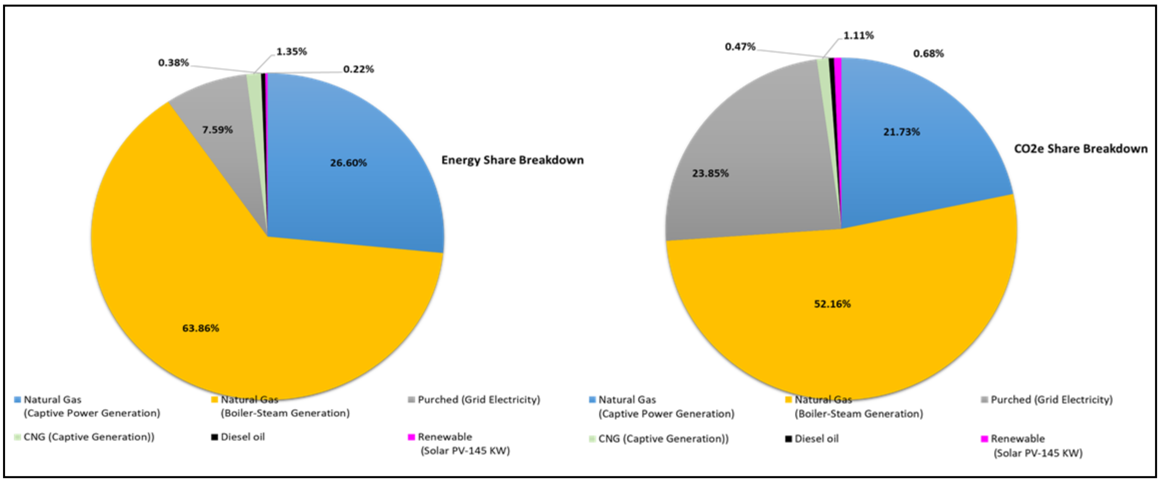
In its production processes, IRIS FABRIC LIMITED effectively harnesses both Electrical and Thermal energy. The operational energy spectrum encompasses Natural Gas, Grid electricity, Diesel oil and solar PV renewable energy as the primary energy sources. Meanwhile, electricity, steam, and compressed air function as secondary "carrier" energies, facilitating the transport of energy within the system. Specifically, in the year of 2023(spanning January to September), the following energy utilization figures as well as tariff structure were recorded:

Table: Source of Energy and Tariff Structure

Source of Energy and Authority	Meter Info	Tariff Structure 2023 in BDT			Total Bill 2023 in BDT	Tariff Structure 2022 in BDT			Total Bill 2022 in BDT
		Flat	Off-Peak	Peak		Flat	Off-Peak	Peak	
Grid Power Dhaka PBS-3 (pally Bidyut Samity)	Meter # 15556739 Sanc.Load: 3000 KW Meter # 09000770 Sanc.Load: 89 KW		12.22	8.81	53460173		7.61	10.56	48464160
Natural Gas (Captive Generator,TGTDCL)	Meter # 4497243 Minimum Load: 174718 CM	26.09	--	--	34190807	10.54	--	--	25099552
Natural Gas (Boiler/Stenter/Dryer,TGTDCL)	Meter # 4524441 Minimum Load: 379440 CM	26.09	--	--	87776658	14.07	--	--	11141123
Compressed Natural Gas(CNG,TGTDCL)		--	--	--	--	--	--	--	--
Diesel ,BPC	Owner Analog Meter	--	--	--	--	--	--	--	--
Petrole for Vehicle	Owner Analog Meter	--	--	--	--	--	--	--	--
Octane for Vehicle	Owner Analog Meter	--	--	--	--	--	--	--	--
Renewable Energy (Solar Energy) Owner	SEMS	--	--	--	--	--	--	--	--

Table: Energy Consumption status

SOURCE OF PRYMARY ENERGY	TOTAL ENERGY CONSUMPTION 2022 (JAN-DEC)-BASELINE					ALL GHGs (Tonnes CO2e)	% SHARE (Tonnes CO2e)
	kWh	Liter	M3	GJ	%		
Natural Gas (Captive Power Generation)	7,019,109	--	1,800,609	70187.74	26.60%	3397.37	21.73%
Natural Gas (Boiler-Steam Generation)	--	--	4,321,947	168469.49	63.86%	8154.61	52.16%
Purched (Grid Electricity)	5,565,639	--	--	20036.30	7.59%	3728.98	23.85%
CNG (Captive Generation))	--	--	91,635	3571.94	1.35%	172.90	1.11%
Diesel oil	--	27,600	--	993.60	0.38%	74.11	0.47%
Eenewable (Solar PV-145 KW)	157,890	--	--	568.40	0.22%	105.79	0.68%
Total	**12,742,638**	**27,600**	**6214191**	**263827.48**	**100%**	**15633.76**	**100.00%**



1.4.1: Energy consumption and production pattern

At IRIS FABRIC LIMITED, The production processes rely on the consumption of both Electrical and Thermal energy, with these two forms of energy working together to produce the final product. The following data showcases the energy consumption and production trends for the baseline year of 2022.

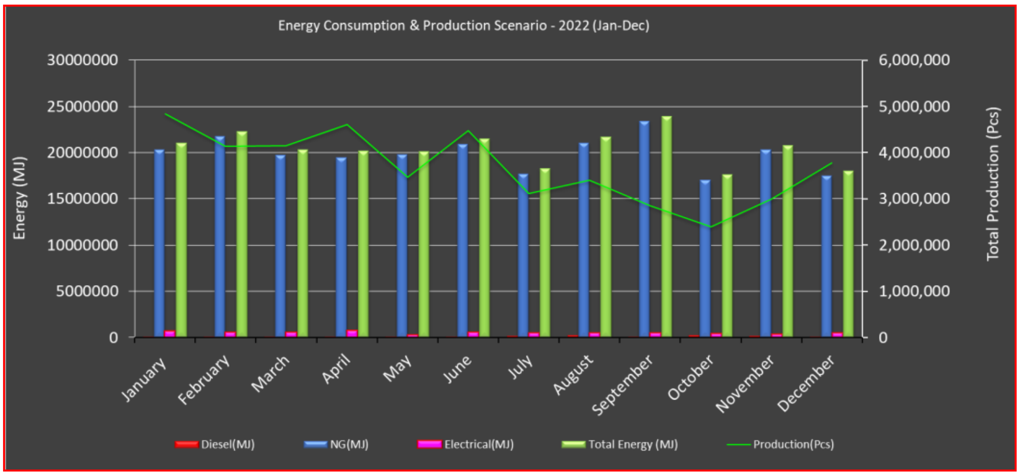


Figure: Energy and Production status

the energy consumption and production data in the table show that the facility uses different amounts of diesel, natural gas (NG), and electrical energy each month, which does not consistently correlate with the production output. For instance, January sees a high total energy use of 20,996,750 MJ for a production of 4,841,794 pieces, indicating a relatively efficient month. In contrast, September's energy use is the highest at 23,893,804 MJ but the production is much lower at 2,854,492 pieces, suggesting less efficiency. The lowest production occurs in October with only 2,394,933 pieces, despite a substantial energy input from diesel at 208,800 MJ. December ends the year with a total energy consumption of 17,978,158 MJ and a production of 3,780,714 pieces, showing an improved efficiency over previous months like September and October.

1.4.2 Specific energy consumption (SEC)

Energy is a valuable commodity for a production facility. From business point of view, it is important to know the consumption of energy per unit production. Information on consumed energy and production can be used to calculate Specific Energy Consumption (SEC) for production. It reflects the energy usage per unit of production and is helpful for comparative analysis within an industry during different periods. If the SEC is known, management will be in a position to control the consumption by taking necessary steps. For this reason, energy audit team evaluated and tabulated Specific Energy Consumption (SEC) during the period of 2022(Jan- Dec) as follows:

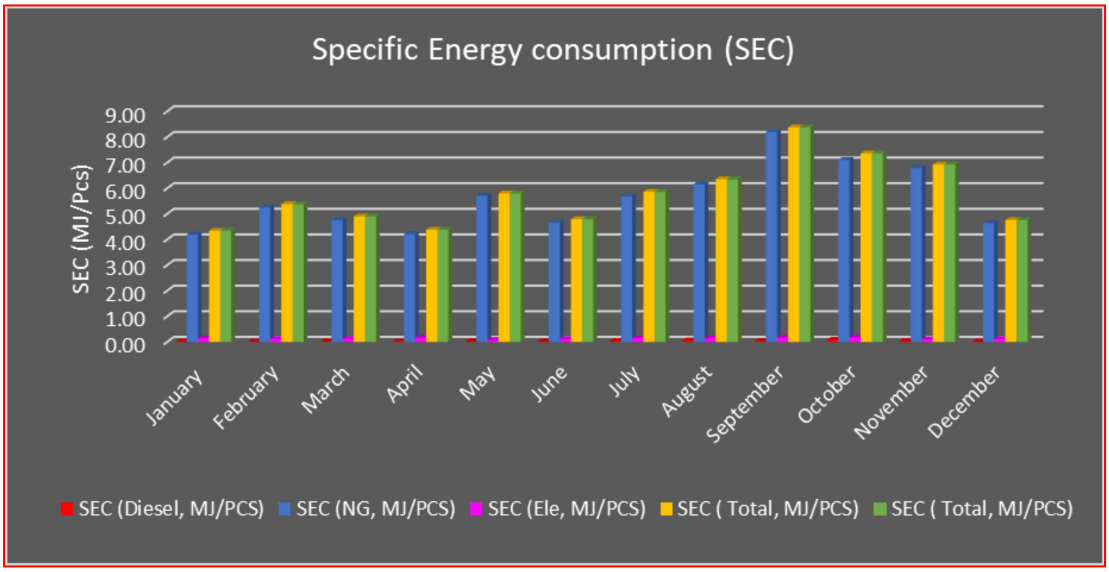


Figure: Specific Energy consumption status

Benchmarking the industries for energy efficiency is a challenging and debatable issue due to wide variations in the working environment. The variation can be due to geography, climate, manpower, working conditions, labor unrest, lack of resource, raw material, energy source, NG pressure correction Factor and lack of exact generalized production pattern etc. Based on the available data, audit team concludes the approximate benchmark from historical energy use pattern

In the baseline year of 2022, The SEC is broken down by energy source: Diesel, Natural Gas (NG), and Electricity (Ele), with the combined total SEC also reported.

Maximum SEC: The highest SEC recorded is in September, at 8.37 MJ/PCS.

Minimum SEC: The lowest SEC is in January, at 4.34 MJ/PCS.

Average SEC: The average SEC across all months is approximately 5.77 MJ/PCS.

Deviation: The percentage deviation from the maximum to the minimum SEC is roughly 48.15%.

Based on this data, a suggested target SEC for the facility to aim for could be the midpoint between the minimum SEC and the average SEC, which would be approximately 5.05 MJ/PCS. This target is ambitious yet attainable, given the facility's performance over the year and would represent a significant improvement in energy efficiency compared to the highest SEC values recorded. By setting this target, the facility would strive to enhance its operational practices to achieve better energy usage rates closer to the most efficient months, like January, while still being mindful of the variation throughout the year.

SECTION-2
Energy Performance Evaluation of Electrical and thermal System (Supply and demand side)

2.0: PERFORMANCE OF ELECTRICAL SYSTEM

2.1: Electrical Energy Infrastructure

The electrical energy infrastructure of the facility is strategically crafted for both resilience and sustainability, integrating a diverse mix of energy sources. This includes natural gas generators, connections to the grid electricity, a solar power system, and diesel generators, each playing a crucial role in the overall energy framework.

Natural Gas Generators:

- The facility has two natural gas-fired generators from Caterpillar, which are renowned for their efficiency and reliability. The primary generator has a significant output capacity of 1500 (KW), Caterpillar brand Model G3512H
- The secondary generator has a capacity of 1030 Kilowatts (KW), Caterpillar brand Model G3516C and it serves as a standby unit. This means it's primarily used when the main generator is not operational, whether due to maintenance or other issues.
- The use of natural gas is typically cleaner in terms of emissions compared to diesel, and having a standby unit ensures that power can be maintained without interruption during periods of grid failure or when the natural gas pressure in the supply line is too low for the main generator to function effectively.

Grid Supply:

- In addition to on-site generation, the facility is connected to the local electrical grid, which provides another source of electricity. This connection is made through a transformer that steps down the high voltage from 33/11 KV to a level that can be used by the facility.
- The transformer has a capacity of 4 MW, with a sanctioned load of 3 MW, which indicates the maximum power it's authorized to draw from the grid.
- Power from the grid is distributed within the facility via two substations with capacities of 2.5 MW and 1 MW, respectively. These substations further step down the voltage from 11 KV to .415 KV for use in the facility. The dual substation

setup provides flexibility and redundancy, ensuring that if one substation encounters issues, the other can continue to supply power.

Rooftop Solar PV System:

- The facility has installed a 145 KW rooftop solar photovoltaic (PV) system, which harnesses solar energy to generate electricity. This system contributes to the facility's power supply, particularly during daylight hours, and reduces the need for electricity from non-renewable sources.
- The inclusion of solar power is also a step towards sustainability, as it reduces the carbon footprint of the facility and aligns with global initiatives to increase the use of renewable energy sources.

Diesel Generators:

- As a secondary backup, the facility has two diesel-fired generators, each with a capacity of 770 KVA. KVA (Kilovolt-Amps) is a unit of apparent power, which includes both real power (KW) and reactive power. This choice of backup is typical for facilities that require a fail-safe against power outages.
- Additionally, there are more units with varying capacities (220 KW, 176 KW, and 1660 KW), which likely serve different sections or have specific purposes within the facility's overall power management plan.
- These generators are crucial for maintaining operations during extended power outages or when both the grid supply and natural gas generators are unavailable.

Overall, this multi-tiered power supply structure is designed to provide a resilient and robust electrical infrastructure. It mitigates risks associated with power outages and energy supply fluctuations by incorporating redundancy and diversification of energy sources, thus ensuring continuous and reliable power for the facility's operations.

2.2: PERFORMANCE OF COMBINED HEAT AND POWER PLANT

IRIS FABIC LIMITED's CHP Plant stands as a model of efficient and sustainable energy management, featuring a 1.5 MW (Caterpillar brand Model G3512H) capacity natural gas-fired generator. This generator is efficiently paired with a cutting-edge exhaust gas boiler system, capable of processing 1.198 tons per hour, adeptly converting waste heat from the generator into valuable thermal energy, thereby significantly boosting the facility's energy efficiency.

The operation of the CHP Plant is characterized by its reliability, maintaining a load factor between 50% and 80% across a 26-day monthly operational cycle. This less-than-ideal load factor is mainly due to consistently low gas pressure in the supply line. The CHP plant is presented below.

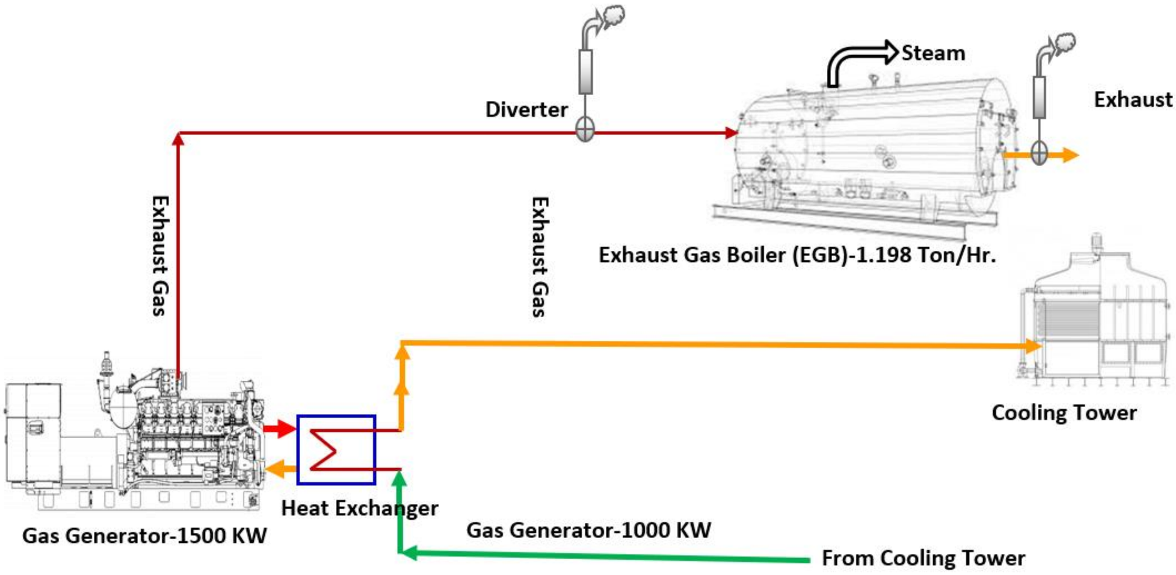


Figure: Visual representation of the existing CHP infrastructure.

2.3: PERFORMANCE OF CAPTIVE GENERATOR

The performance evaluation of individual Gas Gensets was meticulously conducted using the indirect method (ASME PTC 22). This method involved systematic analyses performed with the aid of a Combustion Analyzer, enabling precise measurements of various parameters, including flue gas characteristics and other essential data. All recorded data was thoughtfully entered into a pre-programmed Excel spreadsheet for comprehensive analysis.

Within the framework of the indirect method, the resulting thermal efficiency values were calculated as percentages of the input energy at the generator's front end. This involved the detailed quantification of different types of measurable losses, each expressed as a percentage of the total input energy. These losses encompassed combustion losses, radiation losses, convection losses, unburned fuel losses, excess air losses, and various mechanical losses. The aggregation of these individual losses yielded the total measurable losses. To ascertain the desired overall thermal efficiency of the device, these total measurable losses were then subtracted from the initial 100% input energy.

The performance of Gas Genset as well as projected plant efficiency has been evaluated by indirect method. The rated and operating data of Generators and Waste Heat recovery system are summarized in bellow table.

Table: Measured Flue Gas data

Measured Parameter	Symbol	Unit	Gen # 01
Oxygen Content	O_2	%	10
Carbon Dioxide Content	CO2	%	6.2
Flue Gas Temperature	TS	^{O}C	496
Ambient Temperature	TA	^{O}C	35.8
Carbon Monoxide	CO	ppm	526

Table: Composition of Natural Gas

Composition	Unit	Value
Carbon	%	74.34
Hydrogen	%	24.5
Sulphur	%	0.0
Nitrogen	%	0.254
Carbon Di Oxide	%	0.6
Oxygen	%	0.0
Gross Calorific value of fuel (Natural Gas)	kCal/kg	12940
Density of Natural Gas	kg/m3	0.718
Specific heat of flue gas	kCal/kg.K	0.23
Specific heat of vapor	kCal/kg.K	0.45

Table: Generator performance analysis base on HHV of fuel

Particulars	Unit	Gen-1
Theoretical Air Required	kg/kg of fuel	17.15
Excess Air Supplied (EA)	%	90.91
Actual Mass of Dry Air Supplied/kg of fuel (AAS)	Mass of air/ kg of fuel	32.74
m = Mass of Dry Flue Gas	Kg	33.49
Flue Gas losses		
L1, Heat loss due to dry flue gas (Sensible)	**%**	27.40
L2, Heat loss due to evaporation of water formed due to H_2 in fuel (Latent+Sensible)	**%**	13.48
L3, Heat Loss due to Moisture in Air(Sensible)	**%**	0.94
L4, Heat loss due to incomplete combustion of Carbon (Formation of CO)	**%**	0.28
Total Flue Gas loss	**%**	42.10
Heat Rejection Losses		
L5, Heat Rejection to HT circuit (JW+LO+AC-1)	**%**	13.65
L6, Heat Rejection to LT circuit (AC-2)	**%**	9.10
L7, Heat Rejection to Radiation (Engine side + Alternator side)	**%**	2.98
Total Heat Rejection Loss	**%**	25.73

Combustion and Heat to Electric Efficiency based on HHV		
Combustion Efficiency (100-L1-L2-L3-L4)	%	57.90
Heat to Electric conversion Efficiency on HHV	%	**32.17**
Heat to Electric conversion Efficiency on LHV		**37.18**

Table: Generator flue gas heat loss

Generator	Unit	Gen-1
Sensible Heat Loss with Dry Flue Gas	%	27.40
Sensible Heat Loss with Formed Water	%	3.53
Sensible Heat Loss with Moisture in Air	%	0.94
Total Sensible Heat Loss with Flue Gas	%	31.87
Total Latent Heat Loss with Flue Gas	%	10.23
Total Heat Loss	%	42.10

Table: Generator Plant Output Base Case

Parameters	Unit	GEN-1
Specific Fuel Consumption on HHV	m3/KWh	0.294
Specific Fuel Consumption on LHV	m3/KWh	0.254
Heat rate based on HHV	Mj/Kwh	11.190
Heat rate based on LHV	Mj/Kwh	9.682
Electricity generation per SCM of fuel	Kwh/m3	3.41
Averag demand of each Generator	KW	1080
Average Natural Gas consumption per hour	m3/hr	317.13
Fuel cost of electricity generation	Tk/SCM	26.09
Elect. Gen.cost (consider fuel cost only)	Tk/KWh	7.66

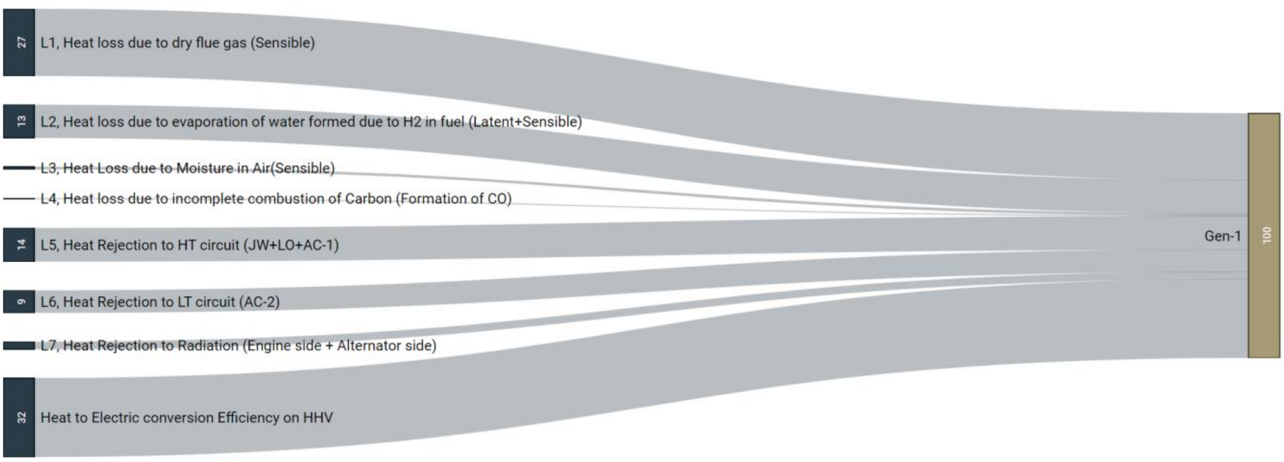


Figure: Generator heat balance Sankey diagram

Note:

Losses listed in item L5 to L7 are estimated from the catalogue based on the operating load and measuring temperature. The catalog value is based on the following condition

(1) Fuel consumption tolerance according to ISO 3046/1
(2) LHV rate tolerance is ± 1.5%.
(3) Heat rejection to jacket water value displayed includes heat to jacket water alone. Value is based on treated water. Tolerance is ± 10% of full load data.
(4) Heat rejection to atmosphere based on treated water. Tolerance is ± 50% of full load data.
(5) Lube oil heat rate based on treated water. Tolerance is ± 20% of full load data.
(6) Exhaust heat rate based on treated water. Tolerance is ± 10% of full load data.
(7) Heat rejection to exhaust (LHV to 77°F) value shown includes unburned fuel and is not intended to be used for sizing or recovery calculations.
(8) Heat rejection to A/C - Stage 1 based on treated water. Tolerance is ±5% of full load data.
(9) Heat rejection to A/C - Stage 2 based on treated water. Tolerance is ±5% of full load data.
(10) Total Jacket Water Circuit heat rejection is calculated as: (JW x 1.1) + (OC x 1.2) + (1AC x 1.05) + [0.753 x (1AC + 2AC) x (ACHRF - 1) x 1.05]. Heat exchanger sizing.

2.3.1: Observations

Generator Air-Fuel Ratio:

The generator is functioning with a 90% air excess, a setting that is in line with the manufacturer's suggested parameters. Nonetheless, achieving additional savings by tuning the air-fuel mixture could be complex, given the significant correlation between the engine's air-fuel ratio and its exhaust emissions.

Heat-to-Electricity Conversion Efficiency:

Under the current operational parameters, the generator boasts a notable heat-to-electricity conversion efficiency of around 32% when measured on the Higher Heating Value (HHV) basis. This efficiency level underscores the generator's capability to effectively transform heat into electrical energy, highlighting a commendable aspect of its performance.

Heat Loss Concerns:

Notably, a significant amount of heat escapes through the engine's jacket water, intercooler, and exhaust gas. This heat loss represents an area where improvements can be made to enhance overall energy efficiency and minimize waste.

Addressing Heat Losses:

To optimize the system and improve energy utilization, addressing these heat losses from the engine's jacket water, intercooler, and exhaust gas is crucial. Implementing effective waste heat recovery methods in these areas has the potential to yield substantial cost savings and further enhance the overall performance of the generators.

Maximizing Energy Efficiency:

By carefully managing excess heat and implementing appropriate heat recovery techniques, the facility can maximize energy efficiency, reduce operating costs, and foster a more sustainable and environmentally responsible operation.

2.4: WASTE HEAT RECOVERY AND UTILIZATION

The performance analysis of the gas generators reveals that approximately 32 % of the input energy is effectively converted into electrical energy, while the remaining energy is wasted through exhaust and cooling systems.
To address this energy wastage and maximize efficiency, there are two viable methods of recovering and reutilizing waste heat from the engine generators:

i) Recovering and Reutilizing High-Temperature Waste Heat from Hot Exhaust:
By capturing the high-temperature waste heat from the hot exhaust gases, it is possible to convert this heat into usable energy.
ii) Another approach involves the recovery and reutilization of waste heat from the various cooling circuits, including jacket water, lube oil, and intercooler cooler. These cooling circuits carry away excess heat from different engine components, and this heat can be effectively recovered and converted into useful energy.

2.5: Status of Exhaust Waste Energy Recovery

The current system impressively converts 32% of the input energy into electrical power, an exceptional achievement based on the Higher Heating Value (HHV). However, about 68% of the energy is not utilized, primarily lost via exhaust gases, the cooling system, and radiation. To counter this, an Exhaust Gas Boiler (EGB) capable of handling 1.198 tons per hour has been installed to recover energy from the exhaust. The detailed analysis below elaborates on the amount of energy reclaimed from the exhaust, exploring further opportunities for energy conservation and the associated cost benefits.

Table: Status Overview of Harnessing Exhaust Waste Heat

Particulars	Unit	Genset-1
Gen Set Overall Conversion Efficiency	%	32.17
Genset exhaust Heat Loss	%	42.10
Ambient Temp, T_a	°C	35
Gen Set Exhaust Gas Temp T_e	°C	496
EGB Inlet Temp, T_1 = (Te-Tr)	°C	470
EGB Inlet Gas C_{p1} Value	kJ/kg-°C	1.099
EGB Outlet economizer Gas Temp, T_2	°C	190
EGB Outlet Gas C_{p2} Value	kJ/kg-°C	1.013
GenSet Exaust Sensible Heat Recovery By EGB $Q_r = \dfrac{m \times (Cp_1 (T_1 - Ta) - Cp2(T2-Ta))}{m \times Cp_1 (T_1 - T_a)}$	%	67.16

Recovering from (Already Achieved by Gen#1) Exhaust by EGB Compared to Initial Supplied Energy to Genset- on GCV	%	28.27
Generator Energy consumption	nm3/yr.	1800609
Energy Saving by EGB	nm3/yr.	509081.409
equivalent Cost saving	BDT/Yr	13281934

2.5.1 ECM 1: Potential Energy Saving by Using Hot Water Module

A Hot Water Generator installation is recommended to utilize the Jacket water heat energy in the plant, where steam is predominantly used to create hot water for various washing processes. This is favored over installing additional Exhaust Gas Boilers (EGBs) as it's not only more cost-effective but also simpler to maintain with local expertise. By storing the produced hot water in a steel insulated tank, it can be directly supplied to different points of use as needed. This approach would substantially reduce the hot water preparation time, which currently involves mixing cold water with steam, thus leading to an increase in production capacity. Furthermore, this strategy would significantly decrease the operational demands on the Natural Gas (NG) fired Boilers, resulting in notable savings on the boiler gas bill.

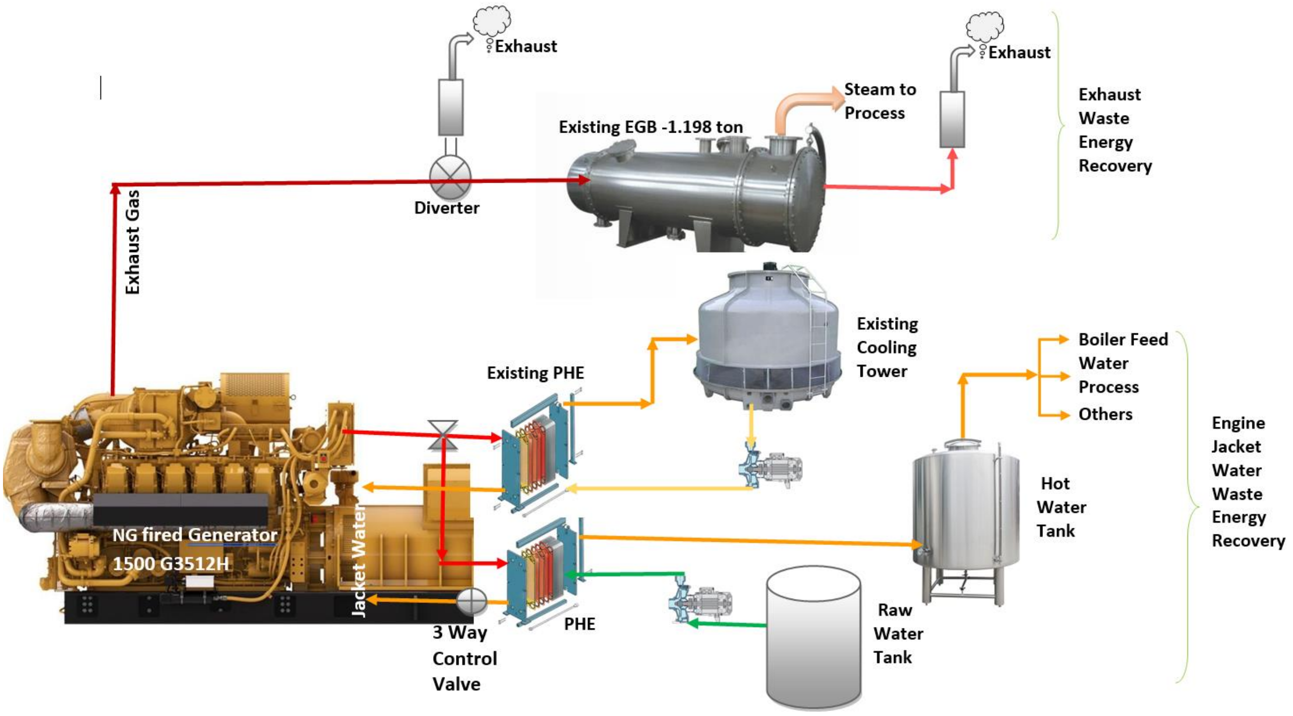


Figure: Proposed Cogeneration (Hot water) System

Table: Potential J/W heat recovery status.

Parameters	Unit	Gen-1
Heat to Electric conversion	%	32.17
Generator input Energy at present operation condition	KW/Hr.	3357
Available heat energy in input	Kj/hr.	12085423
Available heat energy in Engine JW circuit	Kj/hr.	1649660
Useable Heat at the Jacket Water (Considering 60% Efficiency of the Recovery System)	Kj/hr.	989796
Recoverable Heat from Jacket Water (% of Engine Input Heat Energy)	%	8.19%
Hot Water Available Potential (at 65°C from 30 °C cold water)	m3/Hr	6.73
Estimated natural gas saving per hour	nm3/Hr	25
Possible Cooling Effect with an absorption chiller (Consider COP of absorption system is .8)	RT	63
natural gas consumption per year	nm3/Yr	1800609
Estimated Natural gas saving per year	nm3/Yr	147470
Equivalent cost saving per year	BDT	3847489
Estimated investment	BDT	11000000.00
Simple payback period	year	2.86

2.6: ERFORMANCE OF ENERGY DISTRIBUTION SYSTEM

The primary objective of this comprehensive power quality assessment was to evaluate the power quality of a natural gas-fired generator within a synchronous bus system consisting of seven similar generators in the electrical system. The assessment encompassed various aspects of power quality, including Total Harmonic Distortion (THD), system frequency variation, power factor, voltage deviation, imbalance, and other critical parameters. The aim was to identify any deviations from established international standards and benchmarks, as well as to assess potential indirect losses.

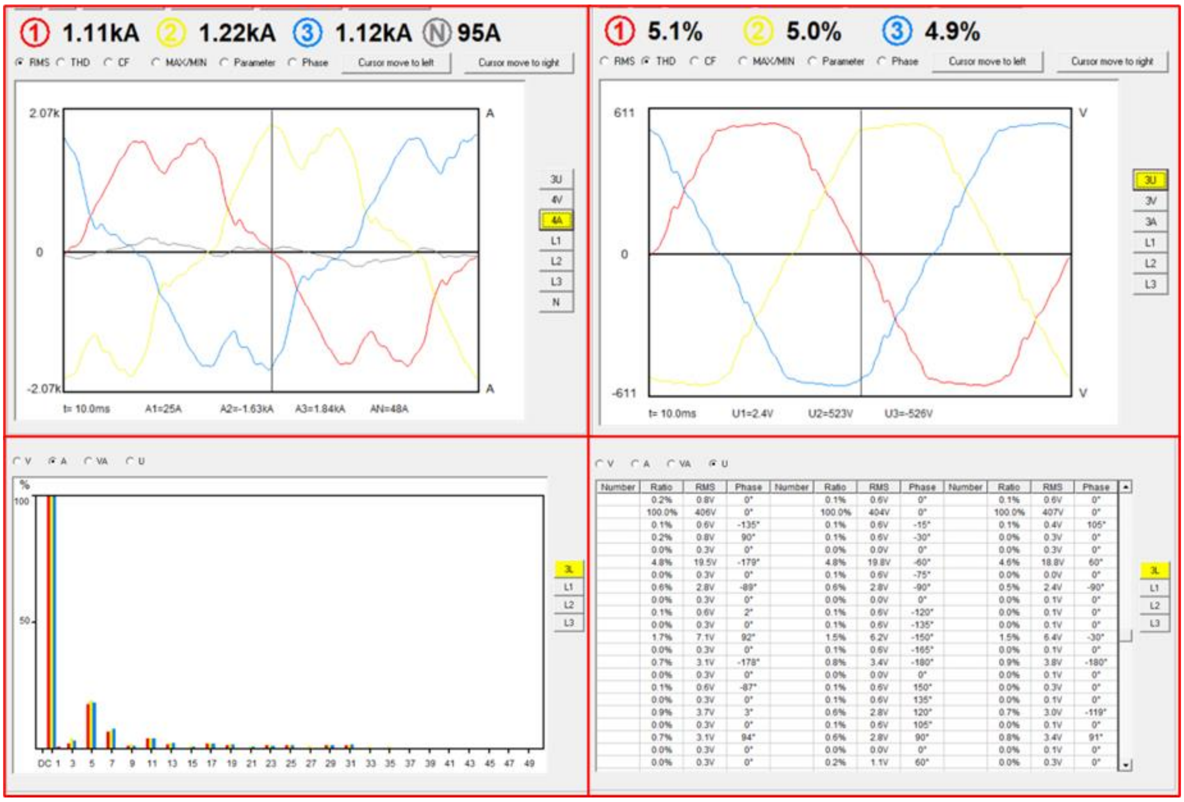


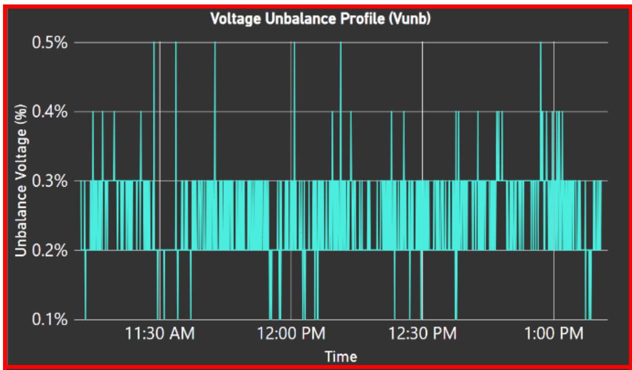
Figure: Electrical system parameters

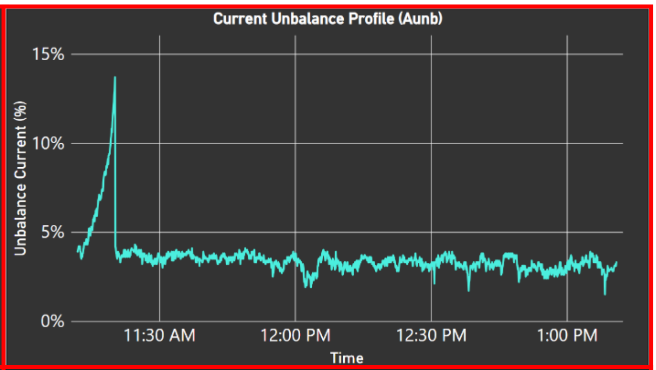
These issues collectively lead to energy losses, both directly and indirectly, while also reducing the safety margin for the electrical system and its equipment. This can result in higher maintenance costs, increased equipment failure risks, and premature aging of equipment. The assessed power quality profile, which encompasses these aspects, is presented below. It underscores the importance of addressing power quality concerns to prevent energy wastage and protect the integrity of the electrical system and associated equipment. The power quality of the electrical system is analyzed, focusing separately on the captive generation and grid sides. Below is a sample graphical representation, accompanied by overall observations and recommendations. For a more in-depth understanding, detailed samples and an extensive analysis are compiled in Appendix-1, illustrating the complete scenario.

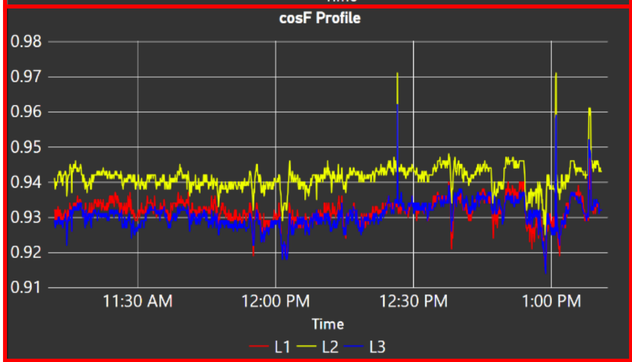
Figure: Power Profile of Generation side

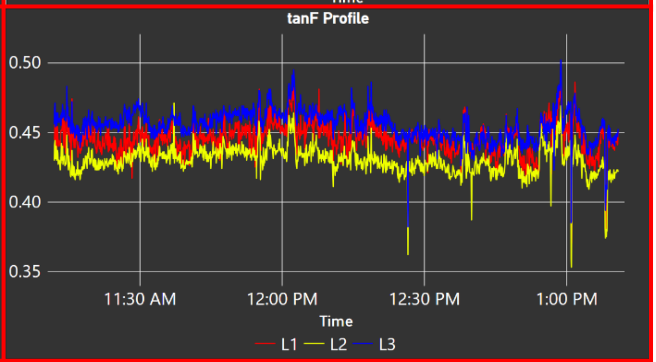
Total Quality. Assured.

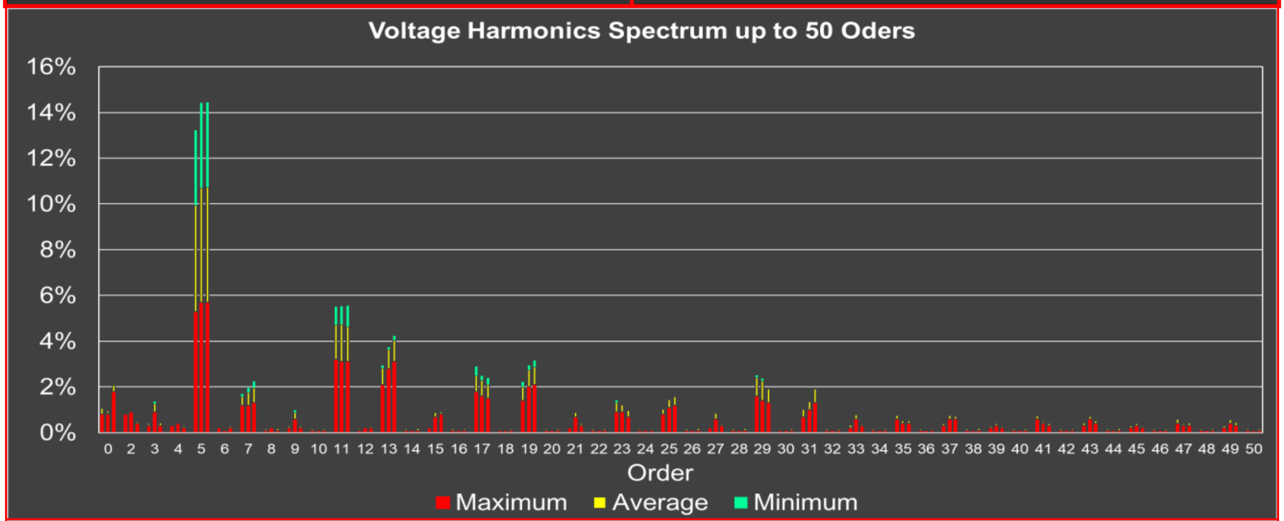
Figure: Power Profile of Generation side

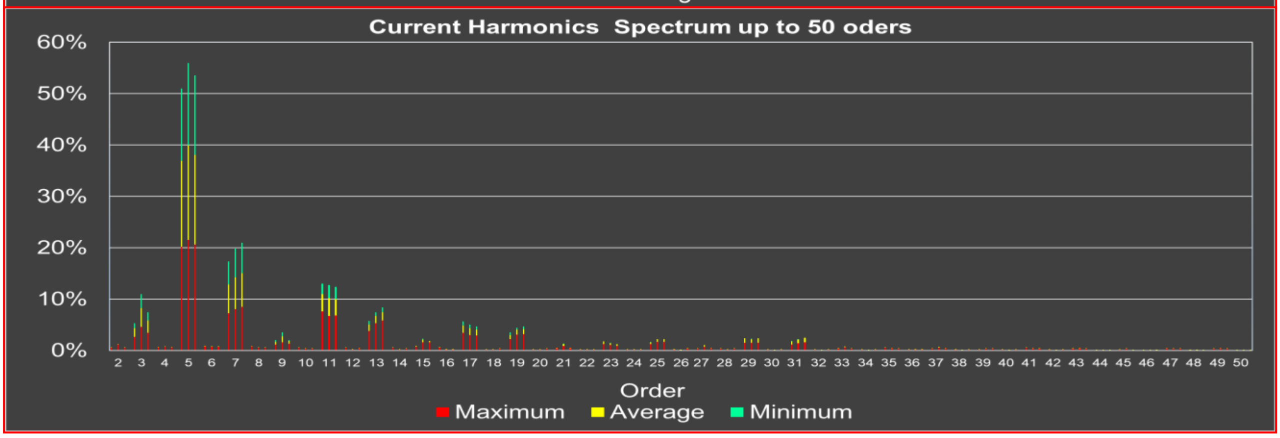

Voltage Unbalance Profile (Vunb)
Unbalance Voltage (%)
0.5%
0.4%
0.3%
0.2%
0.1%
11:30 AM
12:00 PM
12:30 PM
1:00 PM
Time


Current Unbalance Profile (Aunb)
Unbalance Current (%)
15%
10%
5%
0%
11:30 AM
12:00 PM
12:30 PM
1:00 PM
Time


cosF Profile
0.98
0.97
0.96
0.95
0.94
0.93
0.92
0.91
11:30 AM
12:00 PM
12:30 PM
1:00 PM
Time
L1 L2 L3


tanF Profile
0.50
0.45
0.40
0.35
11:30 AM
12:00 PM
12:30 PM
1:00 PM
Time
L1 L2 L3


Voltage Harmonics Spectrum up to 50 Oders
16%
14%
12%
10%
8%
6%
4%
2%
0%
0 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
Order
Maximum
Average
Minimum


Current Harmonics Spectrum up to 50 oders
60%
50%
40%
30%
20%
10%
0%
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
Order
Maximum
Average
Minimum

Harmonics Profile																			
Volatage Profile(V)					Current Profile (A)					Volatage Profile (V)					Current Profile (A)				
Oders	Range	R	Y	B	Oders	Range	R	Y	B	Oders	Range	R	Y	B	Oders	Range	R	Y	B
0th	Max	0.80%	0.28%	0.00%	2nd	Max	0.50%	0.10%	0.00%	11th	Max	3.20%	1.51%	0.80%	12th	Max	0.50%	0.05%	0.00%
	Avg	0.80%	0.19%	0.00%		Avg	1.10%	0.14%	0.00%		Avg	3.10%	1.63%	0.80%		Avg	0.20%	0.06%	0.00%
	Min	1.80%	0.28%	0.00%		Min	0.50%	0.08%	0.00%		Min	3.10%	1.54%	0.90%		Min	0.40%	0.07%	0.00%
2nd	Max	0.80%	0.06%	0.00%	3rd	Max	2.60%	1.70%	1.00%	12th	Max	0.10%	0.06%	0.00%	13th	Max	3.80%	1.23%	0.70%
	Avg	0.90%	0.04%	0.00%		Avg	4.60%	3.62%	2.70%		Avg	0.20%	0.04%	0.00%		Avg	5.30%	1.42%	0.70%
	Min	0.40%	0.08%	0.00%		Min	3.40%	2.40%	1.60%		Min	0.20%	0.07%	0.00%		Min	5.80%	1.59%	1.00%
3rd	Max	0.30%	0.12%	0.00%	4th	Max	0.60%	0.06%	0.00%	13th	Max	2.10%	0.73%	0.10%	14th	Max	0.50%	0.05%	0.00%
	Avg	0.90%	0.36%	0.10%		Avg	0.70%	0.08%	0.00%		Avg	2.80%	0.83%	0.10%		Avg	0.20%	0.06%	0.00%
	Min	0.30%	0.13%	0.00%		Min	0.60%	0.07%	0.00%		Min	3.10%	0.94%	0.20%		Min	0.30%	0.07%	0.00%
4th	Max	0.30%	0.06%	0.00%	5th	Max	20.20%	16.68%	14.10%	14th	Max	0.10%	0.06%	0.00%	15th	Max	0.70%	0.15%	0.00%
	Avg	0.40%	0.04%	0.00%		Avg	21.50%	18.43%	16.00%		Avg	0.10%	0.04%	0.00%		Avg	1.60%	0.47%	0.20%
	Min	0.20%	0.07%	0.00%		Min	20.60%	17.47%	15.50%		Min	0.10%	0.08%	0.00%		Min	1.60%	0.23%	0.00%
5th	Max	5.30%	4.63%	3.30%	6th	Max	0.80%	0.06%	0.00%	15th	Max	0.20%	0.06%	0.00%	16th	Max	0.50%	0.05%	0.00%
	Avg	5.70%	5.01%	3.70%		Avg	0.70%	0.07%	0.00%		Avg	0.70%	0.18%	0.00%		Avg	0.20%	0.06%	0.00%
	Min	5.70%	5.04%	3.70%		Min	0.70%	0.08%	0.00%		Min	0.80%	0.12%	0.00%		Min	0.20%	0.07%	0.00%
6th	Max	0.20%	0.06%	0.00%	7th	Max	7.20%	5.60%	4.50%	16th	Max	0.10%	0.06%	0.00%	17th	Max	3.40%	1.43%	0.80%
	Avg	0.10%	0.04%	0.00%		Avg	8.00%	6.20%	5.60%		Avg	0.10%	0.04%	0.00%		Avg	3.00%	1.30%	0.70%
	Min	0.20%	0.08%	0.00%		Min	8.50%	6.57%	5.90%		Min	0.10%	0.07%	0.00%		Min	2.90%	1.14%	0.60%
7th	Max	1.20%	0.39%	0.10%	8th	Max	0.80%	0.06%	0.00%	17th	Max	1.80%	0.70%	0.40%	18th	Max	0.20%	0.05%	0.00%
	Avg	1.20%	0.56%	0.20%		Avg	0.50%	0.06%	0.00%		Avg	1.60%	0.69%	0.20%		Avg	0.20%	0.06%	0.00%
	Min	1.30%	0.65%	0.30%		Min	0.50%	0.07%	0.00%		Min	1.50%	0.60%	0.30%		Min	0.30%	0.07%	0.00%
8th	Max	0.10%	0.06%	0.00%	9th	Max	1.10%	0.59%	0.30%	18th	Max	0.10%	0.06%	0.00%	19th	Max	2.20%	0.79%	0.50%
	Avg	0.20%	0.04%	0.00%		Avg	1.60%	1.14%	0.80%		Avg	0.10%	0.04%	0.00%		Avg	3.10%	0.93%	0.40%
	Min	0.10%	0.08%	0.00%		Min	1.30%	0.55%	0.20%		Min	0.10%	0.07%	0.00%		Min	3.20%	0.98%	0.50%
9th	Max	0.20%	0.11%	0.00%	10th	Max	0.50%	0.05%	0.00%	19th	Max	1.40%	0.62%	0.20%	20th	Max	0.20%	0.05%	0.00%
	Avg	0.60%	0.28%	0.10%		Avg	0.30%	0.06%	0.00%		Avg	2.00%	0.74%	0.20%		Avg	0.20%	0.05%	0.00%
	Min	0.20%	0.09%	0.00%		Min	0.30%	0.07%	0.00%		Min	2.10%	0.76%	0.30%		Min	0.30%	0.07%	0.00%
10th	Max	0.10%	0.06%	0.00%	11th	Max	7.60%	3.36%	2.00%	20th	Max	0.10%	0.06%	0.00%	21st	Max	0.40%	0.90%	0.40%
	Avg	0.10%	0.04%	0.00%		Avg	6.70%	3.51%	2.50%		Avg	0.10%	0.04%	0.00%		Avg	0.10%	0.28%	0.13%
	Min	0.10%	0.07%	0.00%		Min	6.80%	3.22%	2.40%		Min	0.10%	0.07%	0.00%		Min	0.00%	0.10%	0.00%

Parameters	Range	L1	L2	L3	N	Total	Parameters	Range	L1	L2	L3	N	Total
Voltage (V) (L-N)	Max	236	236	236	1.7	--	Power Factor	Max	0.94	0.94	0.93	--	0.94
	Avg	235.01	234.93	235.07	0.88	--		Avg	0.91	0.92	0.91	--	0.91
	Min	234	234	235	0	--		Min	0.9	0.9	0.89	--	0.9
Voltage Unbalance (%)	Max	0.5					Frequency(Hz)	Max	51.66				
	Avg	0.24						Avg	49.97				
	Min	0.1						Min	48.43				
Current (A)	Max	1480	1630	2120	163	--	Voltage Crest factor (L-L)	Max	1.36	1.37	1.36	--	--
	Avg	1310.81	1457.4	1369.31	102.14	--		Avg	1.36	1.35	1.35	--	--
	Min	900	977	901	71	--		Min	1.35	1.35	1.35	--	--
Current Unbalance (%)	Max	13.7					Voltage Crest factor (L-N)	Max	1.51	1.51	1.5	--	--
	Avg	3.55						Avg	1.49	1.5	1.49	--	--
	Min	1.5						Min	1.48	1.49	1.48	--	--
Voltage (THD) (%) (L-L)	Max	7.1	7.4	7.2	--	--	Current Crest factor	Max	1.58	1.64	1.59	--	--
	Avg	5.53	5.67	5.42	--	--		Avg	1.48	1.52	1.53	--	--
	Min	3.9	4.3	4.1	--	--		Min	1.46	1.48	1.49	--	--
Voltage (THD) (%) (L-N)	Max	6.8	7.3	7.4	--	--	Transformer K-Factor	Max	3.4	3.65	3.64	--	--
	Avg	5.24	5.71	5.67	--	--		Avg	2.25	2.46	2.4	--	--
	Min	3.9	4.3	4.2	--	--		Min	2.06	2.16	1.98	--	--
Current (THD) (%)	Max	23.2	24.6	23.8	--	--	Short Term Flicker	Max	0.09	0.06	0.12	--	--
	Avg	18.23	20.35	19.35	--	--		Avg	0.09	0.06	0.12	--	--
	Min	16	18.3	17.9	--	--		Min	0	0	0	--	--
Active Power (KW)	Max	318.1	349.5	453.3	--	1089	COS ϕ	Max	0.96	0.97	0.96	--	--
	Avg	281.19	314.3	292.91	--	888.4		Avg	0.93	0.94	0.93	--	--
	Min	190.8	209.3	191	--	591.8		Min	0.91	0.93	0.91	--	--
Apparent Power (KVA)	Max	347	381.5	498.9	--	1193	Tan ϕ	Max	0.49	0.47	0.5	--	--
	Avg	307.9	342.19	321.93	--	972.01		Avg	0.45	0.43	0.46	--	--
	Min	212	230.2	212.3	--	654.5		Min	0.37	0.35	0.38	--	--
Reactive Power (KVAR)	Max	142.8	159.9	208.3	--	489.2		--	--	--	--	--	--
	Avg	125.4	135.28	133.54	--	394.22		--	--	--	--	--	--
	Min	90.22	93.8	92.65	--	277		--	--	--	--	--	--

Observation:

Upon conducting an exhaustive power quality assessment of the electrical system, which encompasses voltage deviation, voltage and current imbalance, frequency variation, power factor, voltage flicker, Total Harmonic Distortion (THD), transients, and inrush current, the following key observations have emerged:

1. **Harmonic status:** The Total Harmonic Distortion (THD) assessment reveals that voltage harmonic found in acceptable range but current levels fall within an unacceptable range. For voltage, THD levels follow a classification system: THD up to 5% is considered normal, 5% to 8% signifies significant pollution, and above 8% indicates major pollution. In the case of current, THD levels similarly have categories: THD up to 10% is considered normal, 10% to 50% signifies significant pollution, and above 50% indicates major pollution. This evaluation is in line with internationally recognized standards, including IEC 1000-3-2, IEEE 519-2014, and BS-EN 6100-3-4.
2. **Voltage Deviation**: The voltage levels consistently remain within an acceptable range, both over and under the nominal voltage. These deviations align with the ±10% tolerance stipulated by the National Electrical Manufacturers Association (NEMA MG1), affirming the system's stability and reliability.
3. **Voltage and Current Imbalance:** The electrical system demonstrates minimal voltage and current imbalances, with the voltage imbalance well below the 1% maximum limit and the current imbalance comfortably within the specified threshold of 10%, as per NEMA MG1. These negligible imbalances foster uniform distribution and alleviate equipment stress, culminating in efficient operation.
4. **Frequency Variation and Power Factor:** The system exhibits satisfactory performance concerning frequency variation and power factor. Although the power factor is slightly lower, likely due to a low load factor, it remains within acceptable limits. Frequency variations fall well within defined tolerances, ensuring a stable electrical supply. While enhancements in power factor could yield improved efficiency, the current values do not denote a critical concern.
5. **Voltage Flicker:** The voltage flicker, as assessed by Pst and Plt values, comfortably falls within acceptable limits, complying with the specifications outlined in the IEC 61000-2-2*2 standard. This underpins a consistent electrical supply, especially for sensitive equipment susceptible to voltage fluctuations.
6. **Transients and Inrush Current:** It is noteworthy that no transient voltage fluctuations or inrush currents were detected during the measurement period, underscoring the electrical system's stable and consistent behavior.

Recommendations:

To rectify the identified power quality deficiencies and ensure optimal system performance, the following recommendations are proposed:

1. **Active Harmonic Filter:** It is imperative to promptly install active harmonic filters. These indispensable devices serve as adept conductors of harmony within the electrical system, efficaciously suppressing harmonics across various orders. This intervention will not only reinstate compliance with international standards but also impart a substantial boost to power quality.
2. **Detuned Capacitor Bank**: In order to mitigate the risk of resonance and uphold system stability, the installation of a detuned capacitor bank is strongly endorsed. These capacitors are equipped with harmonic "restrainers" designed to avert resonance while concurrently enhancing power factor.

Addressing these recommendations will usher in a discernible improvement in power quality, circumvent equipment overheating, forestall damage resulting from short circuits and resonance, and engender stability in the power factor. Ultimately, these measures will lead to heightened power utilization efficiency and the potential for cost savings.

2.7: ENERGY PERFORMANCE AT DEMAND SIDE

IRIS FABRIC LIMITED focuses on electricity consumption, energy efficiency, and conservation opportunities in its operations. The company uses advanced and energy-efficient machinery like Printing Machines, Cutting Machines, Sewing Machines, Finishing Machines, Dry Process Machines Cad & Sample Machines. Energy audit team conducted a random energy audit, identifying these as significant energy consumers. To improve energy efficiency and conservation, the following opportunities have been identified:

Optimizing Control Systems: Fine-tuning control systems for machinery to reduce energy waste.

Intelligent Temperature Management: Implementing smart temperature control for heating and cooling to reduce energy usage.

Process Enhancements: Improving production processes to reduce energy consumption while maintaining quality.

Efficient Stitching Methods: Adopting more efficient stitching techniques for textiles.

Modern Techniques: Incorporating modern manufacturing methods and technologies for energy-efficient production.

Better Maintenance: Regular and proactive equipment maintenance to prevent energy losses.

Energy-Efficient Technologies: Using energy-efficient technologies like high-efficiency motors and lighting.

These initiatives align with sustainability goals, showcasing IRIS FABRIC commitment to responsible and efficient energy usage. Sampled machine power consumption data is provided below for reference.

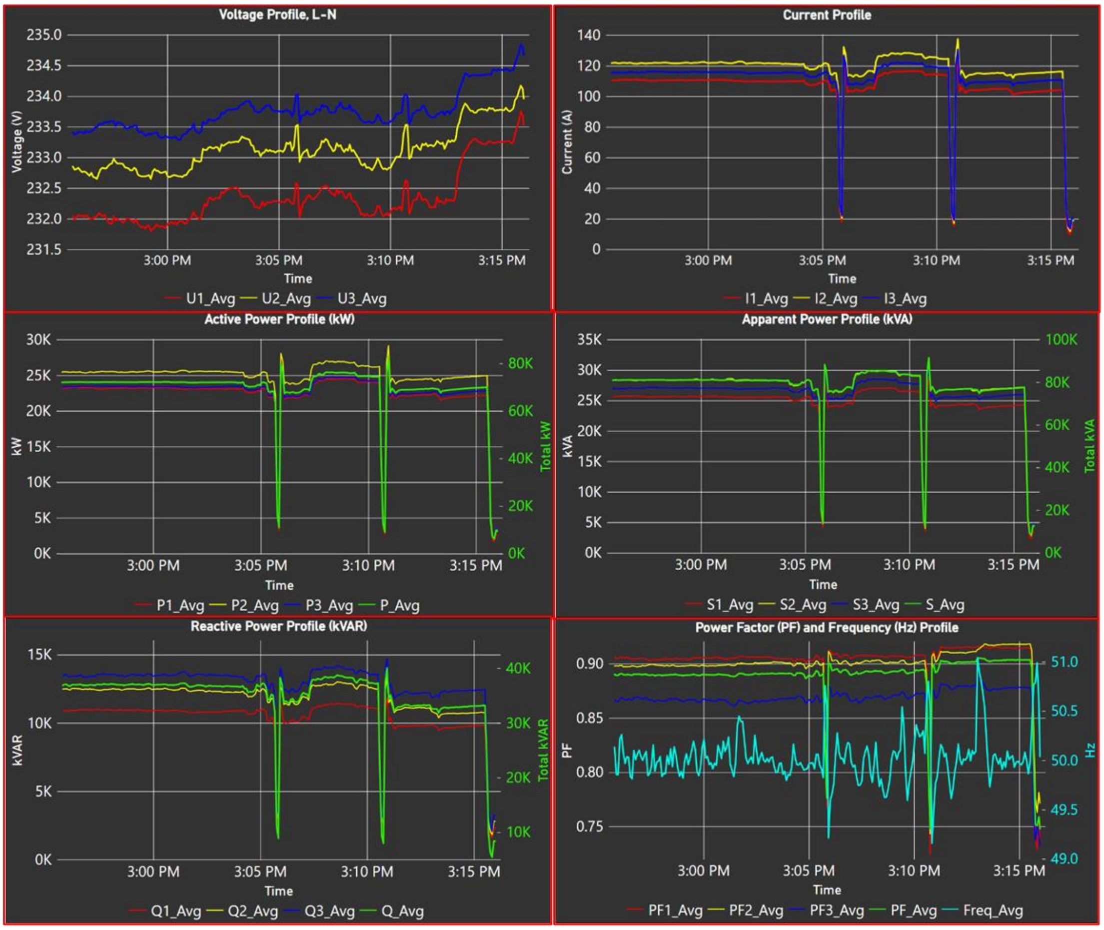


Figure: Bruckner Stenter Machine, 28.8 kW

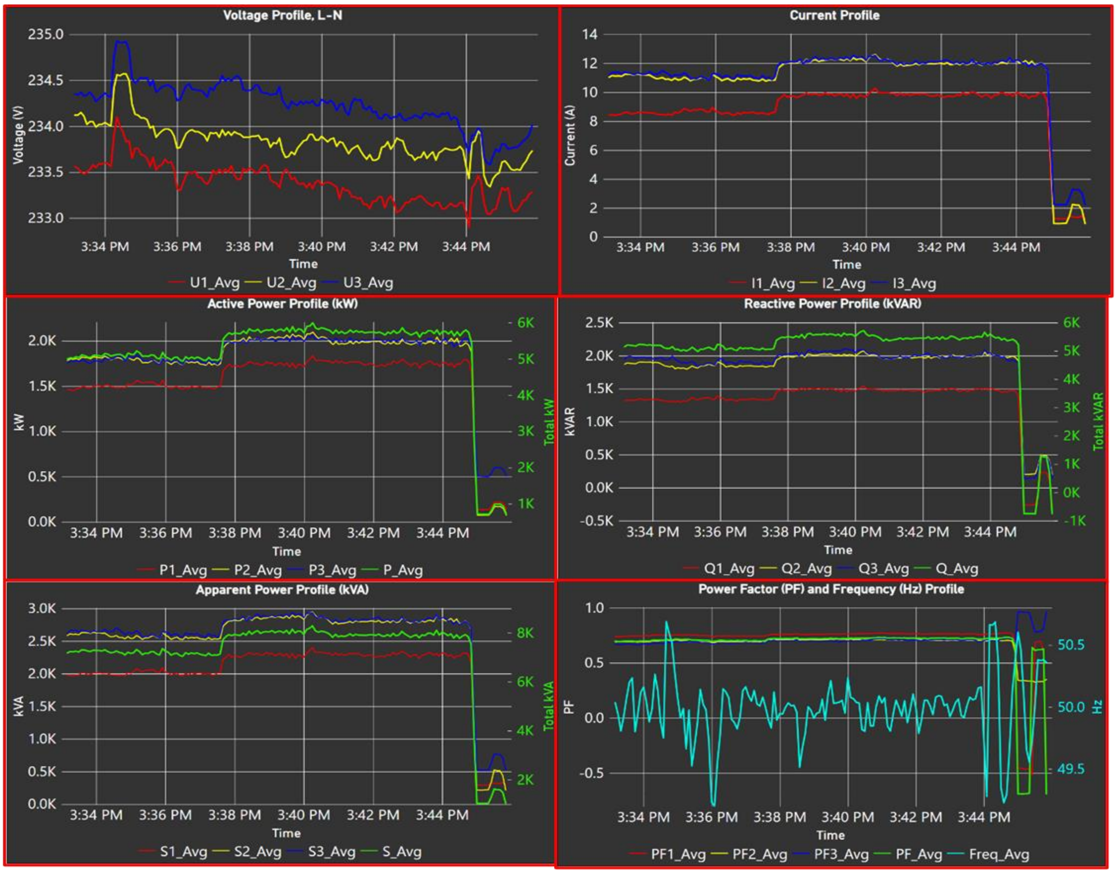


Figure: Sintex machine power consumption data

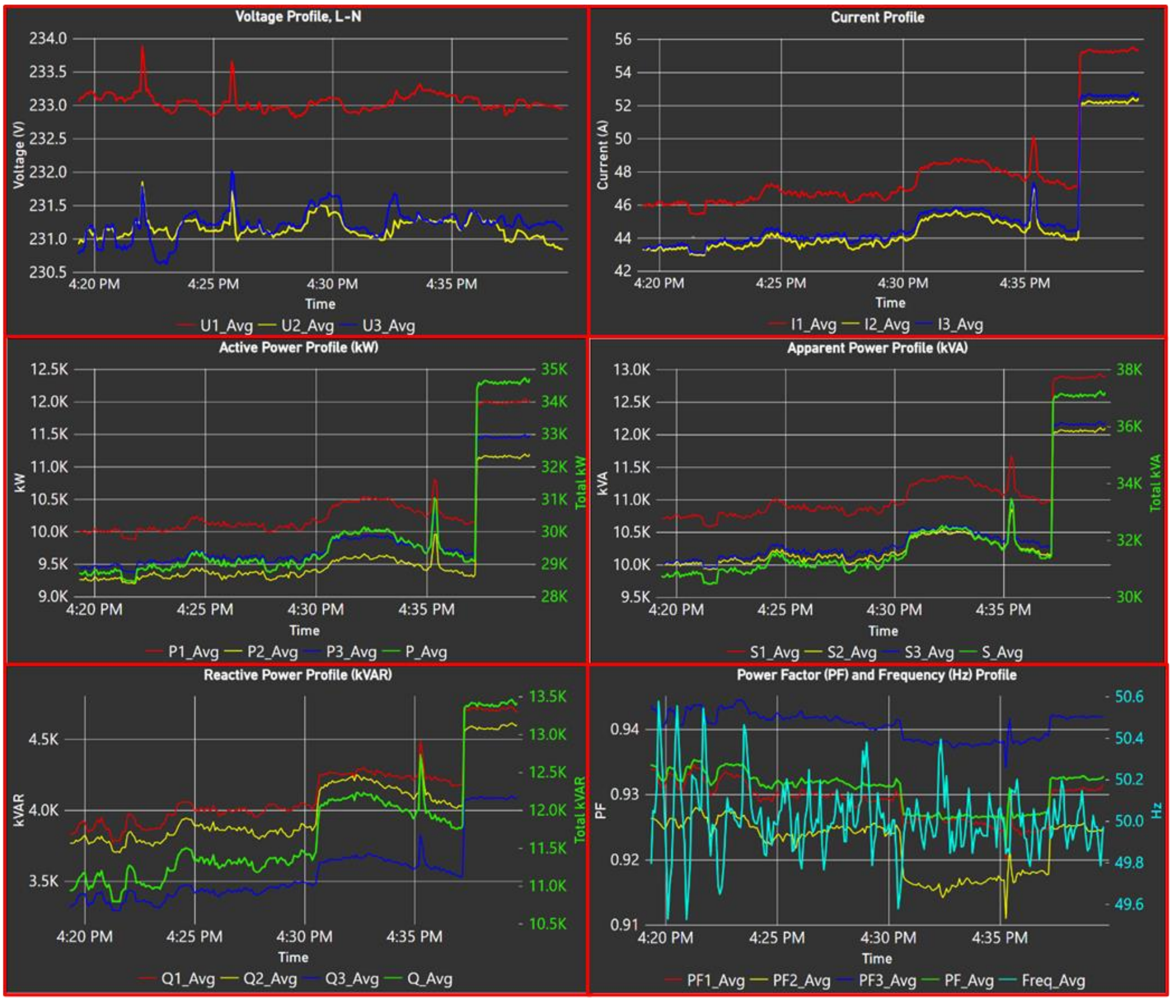


Figure: Tong Geng Dyeing machine (2400 Kg)

Observations:

- The energy audit team, in their assessment of the technological gaps, has randomly reviewed the process equipment and concluded that the machinery is already operating within an acceptable range of energy consumption. This finding indicates that there is no pressing need for major technological retrofits in the current operational practices. Furthermore, such extensive retrofits are not deemed viable given the present energy tariff structure and the operational period.

Recommendations:

- Process Optimization and Energy Conservation: An opportunity for further energy savings through process optimization. This optimization involves a detailed study and adjustment of the resources used in the operational processes, such as water, electricity, steam, and chemicals. However, realizing these potential savings is a time-intensive endeavor, requiring minimum a year-long commitment to study and implement changes, involving both process and energy experts.

- Incremental Process Improvements: Focus on small, incremental improvements in the process machinery that can lead to energy savings without requiring substantial investment or operational overhaul.
- Continuous Monitoring and Adjustment: Implement continuous monitoring systems for real-time tracking of energy usage, allowing for ongoing adjustments and optimizations in the process.
- Employee Training and Awareness: Enhance employee training programs to increase awareness and understanding of energy efficiency, encouraging proactive identification of optimization opportunities.
- Sustainable Practice Integration: Explore integrating more sustainable practices, such as recycling or renewable energy sources, which could provide long-term environmental and financial benefits.
- Long-term Strategy Development: Develop a long-term strategy for gradual implementation of optimization changes, aligning with the company's commitment to sustainability and operational excellence without disrupting current efficiency levels.

2.9: THERMAL (STEAM GENERATION) SYSTEM PERFORMANCE EVALUATION

2.9.1: Thermal Energy Infrastructure

IRIS FABRIC LIMITED boasts a highly resilient thermal energy infrastructure that incorporates cutting-edge technology to ensure efficient heating. The key components of this infrastructure are as follows:

Natural Gas-Fired Boilers: The facility is equipped with two natural gas-fired boilers, each with its own capacity. One boiler has a capacity of 14 tons per hour, while the other is rated at 10.88 tons per hour. These boilers play a crucial role in providing the necessary thermal energy for various production processes. The 10.88-ton/hr boiler serves as a standby source to meet increased demand when required.

Exhaust Gas Boiler (EGB): As part of a strategic energy efficiency initiative, the facility utilizes an exhaust gas boiler with a capacity of 1.198 tons per hour. This innovative boiler captures and harnesses waste heat generated by the natural gas generator. By doing so, it converts what would otherwise be a waste product into a valuable source of thermal energy. This approach not only optimizes energy utilization but also aligns with contemporary practices of waste heat recovery, emphasizing sustainable energy management.

Table: Boiler information

NG Fired Boiler	Particulars	Info
	Brand/Origin	BOSCH
	Model	ULS 12000
	Serial No	129146
	Registration No.	BB-10119
	Capacity (Ton/hr.)	14
	Fuel Used	Natural Gas
	Feed Water Temp	90 deg.C
	Operation Pressure (Kg)	7.4~8.0
	Economizer	Installed
	Operation Schedule (h/day)	24

Table: Boiler Plant status

PARTICULARS	NGB (1-2)		EGB	
	YES	NO	YES	NO
Feed Water Flow Meter	√		√	
Softener plant	√		√	
Softener Water Test Report	√		√	
Feed Tank	√		√	
Feed Tank Insulation	√		√	
Temperature Gauge In Feed Tank	√		√	
Condensate Return Line to Feed Tank	√		√	
Boiler Insulation	√		√	
Steam Pressure Gauge	√		√	
Steam Temperature Gauge	√		√	
Steam Flow Meter	√		√	
Blow Down Water Test Report	√		√	

Economizer Status	√		√	
Economizer Input Pressure Gauge	√		√	
Economizer Input Temperature Gauge	√		√	
Economizer Output Pressure Gauge	√		√	
Economizer Output Temperature Gauge	√		√	
Temperature Gauge In Exhaust Line	√		√	
Header Insulation	√		√	
Pressure Gauge In Header	√		√	
Steam Line Insulation	√		√	
Condensate Return Line	√		√	
Condensate Return Line Insulation	√		√	
Steam Trap, Flange, Strainer & Valve Insulation	√		√	

2.10: BOILER PERFORMANCE EVALUATION

The evaluation of boiler performance at IRIS FABRIC has been meticulously conducted through the utilization of the indirect method, in accordance with renowned standards such as the British Standard BS 845:1987 and the USA Standard ASME PTC-4.1 Power Test Code Steam Generating Units. This rigorous evaluation process aligns with the practices upheld by the Bureau of Energy Efficiency (BEE), which similarly employs the indirect method – often referred to as the heat loss method.

Throughout these calculations, the Higher Heating Value (HHV) of the provided fuel has been employed as a cornerstone parameter. This ensures a comprehensive and accurate assessment of the boiler's efficiency and energy utilization. The technical specifications of the boiler under scrutiny are outlined below, offering a comprehensive insight into its capabilities and characteristics.

Table: Measured flue gas parameter in boiler

Measured Parameter	Symbol	Unit	Boiler-10119
Oxygen Content	O_2	%	7.1
Carbon Dioxide Content	CO2	%	7.8
Flue Gas Temperature before economizer	TS	^oC	233
Flue Gas Temperature after economizer	TS	^oC	180
Ambient Temperature	TA	^oC	29.4
Carbon Monoxide	CO	ppm	3.0

Table: Composition and properties of natural gas

Particulars	Unit	NG
Carbon	%	74.34
Hydrogen	%	24.5
Sulphur	%	0.0
Nitrogen	%	0.6
Carbon Di Oxide	%	0.6
Moisture	%	0.018
Oxygen	%	0.0
Gross Calorific value of fuel	kCal/kg	12940
Density of fuel	kg/m3,	0.718

Specific heat of flue gas	kCal/kg.K	0.23
Specific heat of vapor	kCal/kg.K	0.45

Table: Boiler performance evaluation

Particulars	Unit	Boiler-10119
Theoretical Air Required	kg/kg of fuel	17.15
Excess Air Supplied (EA)	%	51.08
Actual Mass of Dry Air Supplied/kg of fuel	Mass of air/ kg of fuel	25.91
m = Mass of Dry Flue Gas	Kg	26.66
Flue Gas losses		
L1, Heat loss due to dry flue gas (Sensible)	%	7.14
L2, Heat loss due to evaporation of water formed due to H_2 in fuel (Sensible)	%	1.15
L3, Heat loss due to evaporation of water formed due to H_2 in fuel (Latent)	%	9.95
L4, Heat Loss due to Moisture in Air(Sensible)	%	0.24
L5, Heat loss due to incomplete combustion of Carbon (Formation of CO)	%	0.00
L6, Heat Rejection to surface radiation	%	1.00
Overall Boiler Thermal Efficiency		
Overall Boiler Thermal Efficiency (100-L1-L2-L3-L4-L5-L6)	%	80.51

Table: Calculated boiler fuel consumption

Particulars	Unit	Boiler#10119
Boiler capacity	Ton/Hr	14.00
Average load factor	%	70%
Avg. Feed Water temparature	deg.C	30.00
Cold Feed Water enthalpy	Kj/Kg	125.52
Generated steam pressure	Kg/Cm2	8.00
Generated steam temparature	deg.C	174
Enthalpy of generated steam	Kj/Kg	2772
Heat Required per kg of Steam	Kj/Kg	2646.48
available heat energy in steam (consider @ 70 %Load factor)	kj/Hr	25935504
Boiler overall thermal efficiency	%	80.51
Supplied input energy	kj/Hr	32214016
Natural Gas consumption	nm3/Hr	826
Specific fuel consumption	m3 of fuel/Kg of steam	0.3443
Fuel consumption per ton of steam	kg of fuel/Ton of steam	344.343

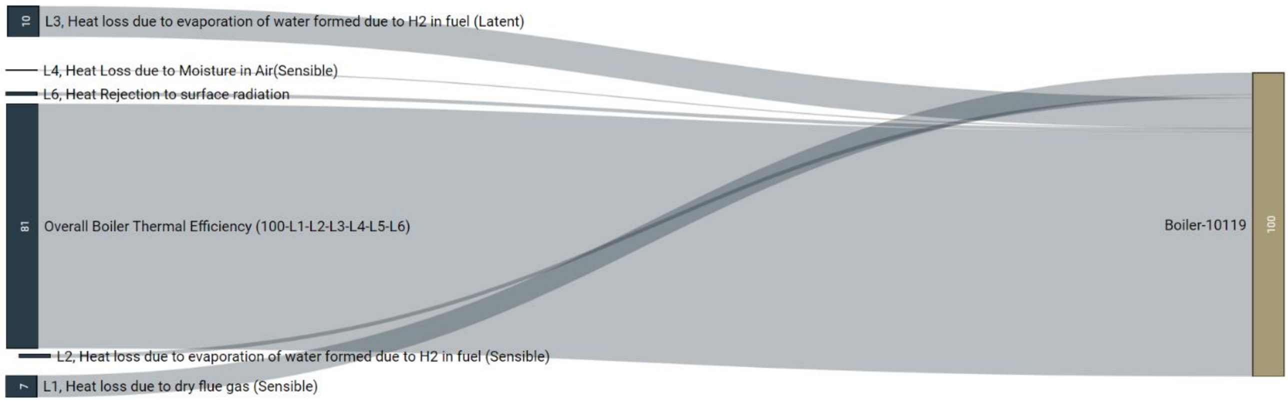


Figure: Boiler heat balance Sankey diagram

Note: assumption

The plant's output in the base case was established based on the following assumptions:

I. The boiler operates continuously at the measured efficiency.
II. Environmental effects are not considered when evaluating the boiler's performance.
III. The boiler operates at 80% loading of its actual capacity throughout its entire operational period.

2.11: Energy Conservation Measures

ECM-2: Energy saving(conservation)by air-fuel ratio adjustment

The analysis of flue gas indicates an excess of air beyond the stoichiometric requirement for complete fuel combustion (BB# 10119). To minimize stack loss effectively, adjusting the air-fuel ratio is crucial. Modifying the air-fuel ratio will help maintain an acceptable level of excess air in the flue gas, thus reducing stack loss within an achievable range. By aiming for an excess air range of 15-20% for Natural Gas, combustion efficiency can be heightened, preventing unnecessary heat loss through excessive air.

Recommendation: Optimize the air-fuel ratio for the Natural gas boiler. This adjustment is anticipated to enhance efficiency by 2.05 % based on the Higher Heating Value (HHV) of the fuel.

Table : Boiler air fuel ratio adjustment status

Particulars	Unit	Boiler-10119
Theoretical Air Required	kg/kg of fuel	17.15
Excess Air Supplied (EA)	%	16.67
Actual Mass of Dry Air Supplied/kg of fuel	Mass of air/ kg of fuel	20.01
m = Mass of Dry Flue Gas	Kg	20.76
Flue Gas losses		
L1, Heat loss due to dry flue gas (Sensible)	%	5.54
L2, Heat loss due to evaporation of water formed due to H_2 in fuel (Latent+Sensible)	%	11.10
L3, Heat Loss due to Moisture in Air(Sensible)	%	0.19
L4, Heat loss due to incomplete combustion of Carbon (Formation of CO)	%	0.02
L5, Heat Rejection to surface radiation	%	1.00
Boiler Thermal Efficiency (100-L1-L2-L3-L4)	%	83.16
Boiler Overall Thermal Efficiency After Tuning Up based on GCV (100-L1-L2-L3-L4)	%	82.16
Average Boiler Thermal Efficiency of All 2 Boilers Before Tune Up (Old Efficiency)	%	80.51
Boiler Energy Saving Potential Over Present Business as Usual Consumption	%	2.05
Boiler Energy consumption in year 2022	nm3/Yr	4321947
Boiler Energy Savings Potential in Future	nm3/Yr	88448
Money Saving Potential in Boiler Gas Saving (NG Tariff for Boiler Tk. 11.77/nm3)	BDT/Yr	2307621
Estimated investment (burner tuned up)	BDT	50000
Sample payback period	Yr	0.02

Note:

___

(Complete combustion of fuel requires a stoichiometric amount of air, but real-world conditions are seldom ideal. To ensure thorough fuel combustion, extra air, known as excess air, must be introduced. Excess air signifies the surplus air supplied compared to the theoretical requirement. Typically expressed as a percentage, such as 15% excess air, it implies that the combustion process employs 115% of the theoretically necessary air. For this specific type of Natural Gas (NG), optimal boiler efficiency falls within the 10-20% range of excess air.)

2.12: Energy Conservation Measures

ECM-3: Energy Efficiency improvement condensing Economizer

Condensing economizer is designed to condense the flue gases. As a result, it can have recovered both sensible and latent heat. Generally, boiler efficiency can be increased by 1% for every 4.44°C (40°F) reduction in flue gas temperature. Economizer can save as much as 1% fuel cost per 10- degree rise in feed water temperature. Condensing economizer can be more efficient as it can have a lower outlet exhaust temperature and take advantage of the energy in condensed flue gases. Both the sensible and latent heat contained in the flue gases are transferred to the water. So it is recommended to install condensate economizer for more recovery (estimated 10% more than existing). Estimate energy saving and associated cost is presented below.

Table: Exhaust waste heat recovery status

Particulars	Unit	Boiler
Boiler overall Thermal Efficiency (Measured).	%	80.50
Total exhaust sensible and latent heat loss	%	19.50
Ambient Temp, T_a	°C	30
Economizer Flue Gas inlet Temp, avg T_1	°C	200
Economizer Inlet Gas C_{p1} Value	kJ/kg-°C	1.099
Economizer Flue gas outlet Temp, T_2	°C	80
Economizer Outlet Gas C_{p2} Value	kJ/kg-°C	1.013
Boiler Exaust Sensible Heat Recovery By Economizer, Q_r	%	72.89
m x(Cp_1 (T_1 - Ta)-Cp2(T2-Ta))		
Q_r = ---------------------------------------		
m x Cp_1 (T_1 - T_a)		
Recovering from Gen Exhaust by Economizer Compared to Initial Supplied Energy to Boiler on GCV	%	14.21
Average Improvement of boiler	%	15.22
Boiler Energy consumption in 2022	nm3	4321947
Natural Gas saving per year	nm3	657800.33
Natural gas cost saving year	BDT	17162010.70
Anticipated investment	BDT	7000000
Product lifetime	Year	10
Simple Payback period	year	0.41

2.13: ALREADY PRACTICED ENERGY EFFICIENCY MEASURES IN STEAM GENERATION SYSTEM

The facility takes a proactive approach to energy conservation within its steam generation system, implementing several key measures to enhance efficiency and sustainability. These measures not only optimize the utilization of resources but also contribute to reducing environmental impact.

Condensate Recovery: IRIS FABRIC places a strong emphasis on condensate recovery. This practice involves collecting and returning condensate (the condensed steam) to the feed pump. By doing so, the facility maximizes the reuse of water and heat energy, resulting in significant energy savings. It not only conserves water resources but also reduces the energy required to heat incoming water.

Economizer Installation: The facility has installed economizers in its steam generation system. Economizers recover heat from the flue gas and transfer it to the feedwater, preheating it before it enters the boiler. This preheating process significantly improves the energy efficiency of the system, reducing fuel consumption and operating costs.

Water Treatment and Softener Plant: IRIS has developed a comprehensive water treatment process, ensuring that raw water sourced from the ground meets the required quality standards for steam generation. The incorporation of a softener plant further enhances water quality, preventing scale buildup in the boiler system and maintaining its efficiency.

Good Insulation Practices: The facility has implemented effective insulation throughout the steam generation system. This insulation helps retain heat, preventing energy losses and ensuring that the steam remains at the desired temperature as it travels through the system. Good insulation practices are vital for maintaining high energy efficiency. Currently, some places ,small valves and flanges remain uninsulated. To further optimize performance and minimize heat loss, it is strongly recommended to insulate these exposed components. This additional step will further optimize system performance and conserve energy. Thermal imaging surveys have been conducted to assess heat loss across the facility, and the associated costs in terms of surface area have been detailed in the appendices.

TDS-Based Blowdown System: The facility has developed and implemented a Total Dissolved Solids (TDS)-based blowdown system. This system helps manage the concentration of impurities in the boiler water, ensuring that it remains within acceptable limits. By efficiently controlling blowdown, the facility minimizes water and energy wastage, contributing to energy conservation.

Enhancing Garment Ironing Efficiency with G Trap: In garment ironing, a significant amount of steam is traditionally wasted, with only a fraction actually reaching the fabric. However, by implementing a "g trap" system, energy efficiency has been greatly improved. This system minimizes steam wastage, directing it effectively to the fabric when needed. This not only reduces energy consumption but also contributes to sustainability and cost savings in garment production.

2.14: ECM-4: ENERGY CONSERVATION MESURE BY IMPROVENT OF INSULATION

Present Practice:

IRIS FABRIC LIMITED relies heavily on a substantial quantity of steam to meet the process heating requirements in various production areas. The steam is generated and distributed through insulated distribution lines. A physical survey revealed that the overall condition of the insulation on these steam distribution lines is generally good. However, certain sections of the insulation were found to be damaged or ineffective.

As a consequence of this damaged insulation, a significant amount of heat energy from the steam is radiating out, leading to the condensation of some steam within the distribution lines. This condensed steam is subsequently drained out through traps. During the survey, the surfaces of the steam lines were examined using sophisticated electronic infrared thermal imaging technology. It was estimated that approximately 4% of the total produced steam was being condensed in the distribution lines due to uninsulated or poorly insulated segments.

This level of steam loss is higher than the acceptable industry standard, which typically allows for up to 2% loss. To prevent this substantial loss, it is crucial to address the damaged insulation through thorough inspection and maintenance. By implementing proper and effective reinsulation measures, it is possible to reduce the amount of steam needed to be produced by the gas-fired boilers, leading to significant gas savings.

Recommendation:

To mitigate the excessive steam loss due to damaged or ineffective insulation in the distribution lines, we recommend the following actions:

Thorough Inspection: Conduct a comprehensive inspection of all steam distribution lines to identify damaged or poorly insulated sections. Utilize sophisticated technologies such as infrared thermal imaging to detect areas of concern accurately.

Immediate Reinsulation: Address the identified damaged or ineffective insulation promptly by reinsulating the affected areas with high-quality insulation materials. Ensure that the insulation meets industry standards and is properly installed to minimize heat loss.

Regular Maintenance: Implement a routine maintenance schedule to monitor the condition of insulation and promptly address any signs of wear or damage. Preventive maintenance will help maintain the efficiency of the insulation over time.

Energy and Cost Savings: Calculate the energy and cost savings resulting from reduced steam loss due to improved insulation. These calculations should take into account the reduced gas consumption by the boilers.

Training and Awareness: Train personnel responsible for maintenance and insulation to recognize the importance of maintaining effective insulation and to promptly address any issues that may arise.

By implementing these recommendations, IRIS FABRIC LIMITED can significantly reduce steam loss, enhance energy efficiency, and realize substantial cost savings. This proactive approach not only contributes to the company's bottom line but also aligns with sustainable energy management practices. .

Table: Insulation loss and cost benefit status

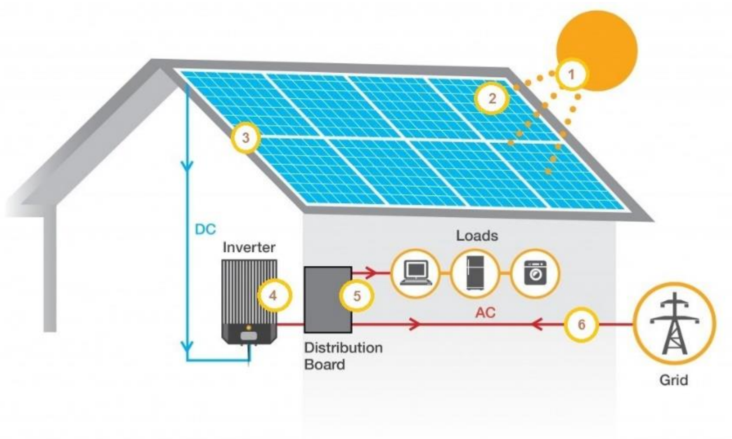
Particulars	Unit	Value
Total Annual gas consumption by all the gas fired Boilers.	nm3/yr	4321947
Savings of extra steam production by boilers	%	2%
Direct boiler gas Savings Potential	nm3/yr	86439
Present Industrial Gas tariff	Tk./nm3	26.09
Direct cost saving potential	Tk./yr	2255192
Annual energy saving potential	MKJ/yr	3294101564
Estimated Investment required for reinsulating uninsulated and damaged insulation lines	BDT	1500000
Considering about 5% yearly maintenance cost	BDT	75000
Simple Payback	Year	0.69
project lifetime	Year	10

SECTION-3
Renewable Energy opportunities

3.1: Introduction: Renewable energy is a critical component of sustainability. It provides clean, abundant, and environmentally friendly alternatives to fossil fuels, helping combat climate change and reduce pollution while promoting economic growth and energy security.

3.2 ECM-5: Harnessing cost reduction and energy preservation by implementing 100 KW solar PV net metering system atop the factory roof.

In addressing its electricity requirements, IRIS FABRIC LIMITED presently relies on captive generation, Grid power and small part of renewable energy having capacity 145 KW. To proactively transition towards sustainable energy practices, a strategic proposition involves integrating renewable energy sources. This entails the installation of a Solar Photovoltaic (PV) net metering system atop the factory's roof, effectively offsetting a portion of the electricity demand currently met through the grid. The result would be a substantial reduction in the consumption of fossil fuel-based primary energy at conventional power stations.



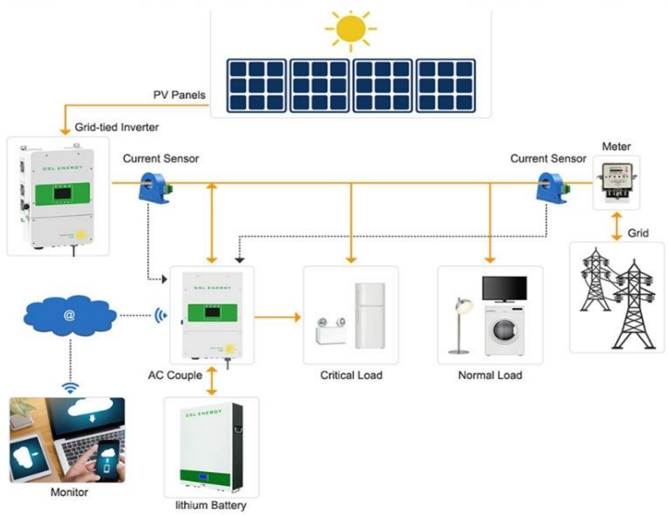


Figure: Solar PV roof top system

The factory's available rooftop space presents a promising opportunity. Initial assessments indicate that the installation of a Solar PV system with a capacity equivalent to 70 kW is feasible. This prospective installation holds the promise of tangible benefits, as it symbolizes a deliberate move towards embracing sustainable energy solutions. By harnessing the sun's energy to generate electricity, BTL not only contributes to mitigating carbon emissions but also conserves finite fossil fuel resources.

The incorporation of a Solar PV net metering system extends beyond a mere energy diversification strategy. It embodies a strategic investment that enhances energy security, fosters cost savings, and exemplifies environmental stewardship. As the Facility charts its course into the future, the adoption of solar energy epitomizes a commitment to sustainable progress, aligned with the global momentum towards cleaner and more resilient energy alternatives.

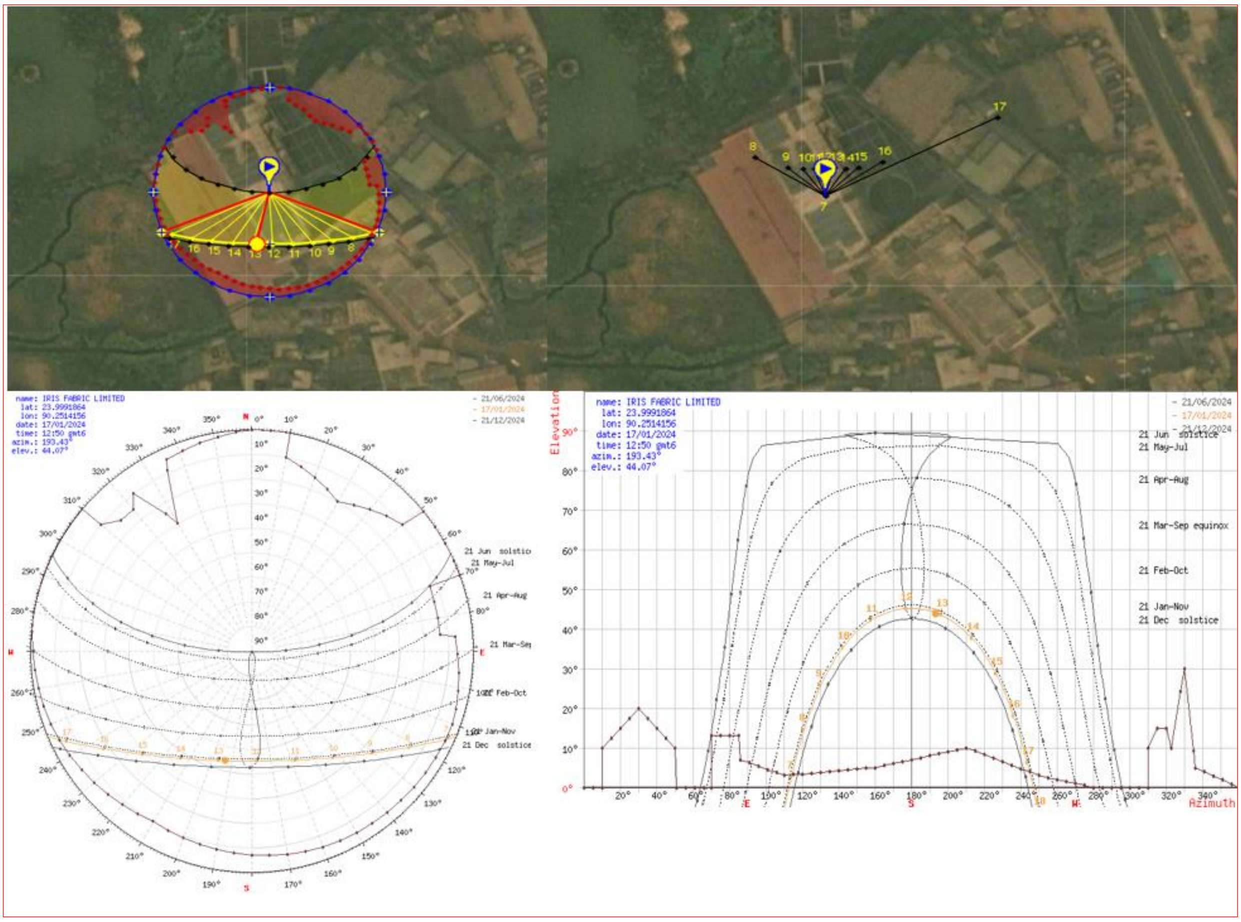


Figure: Sun path of proposed project site

Solar irradiation profile

The project area benefits from a consistent influx of solar energy year-round, with an average of 4.94 kWh/m^2/day (Global) on a horizontal surface and 20° tilted surface. Notably, the period from January to April offers the highest solar energy potential, with March standing out as the pinnacle, boasting 5.96 kWh/m^2/day.

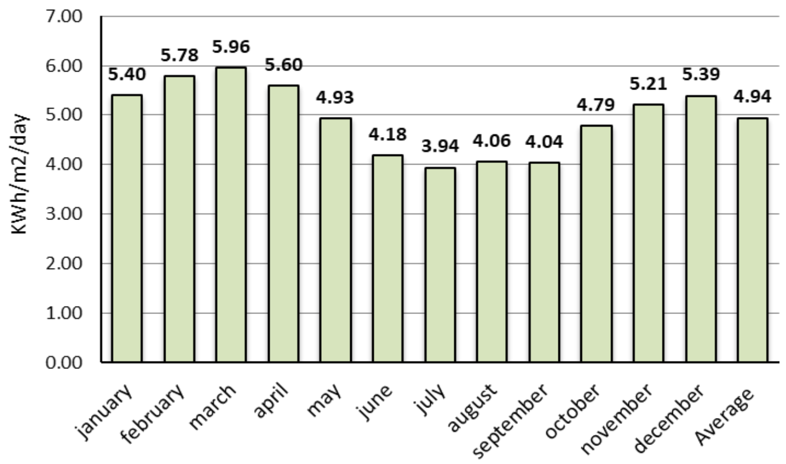


Figure: solar irridance profile

During this period, solar panels can harness the maximum energy due to extended hours of sunshine and favorable conditions. The transition to the monsoon season brings a decrease in solar irradiance, and consequently, solar energy capture. July marks the nadir of solar irradiance, with a minimum value of 3.94 kWh/m^2/day.

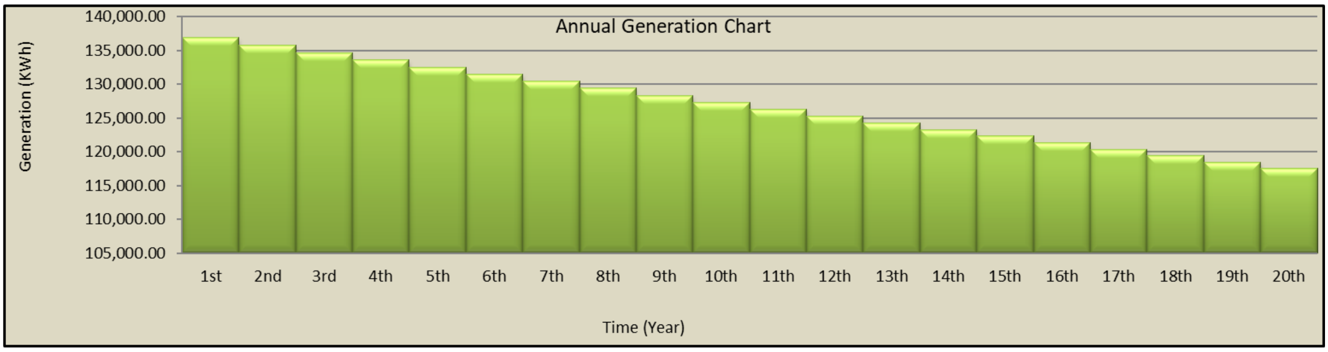
This variation in solar energy availability underscores the importance of strategic planning when considering the installation of solar panels. Capitalizing on the months of heightened solar irradiance, particularly during the peak in March, can maximize the energy generation potential of the solar PV system. Conversely, during the monsoon months, the system's output may be relatively lower due to reduced solar exposure.

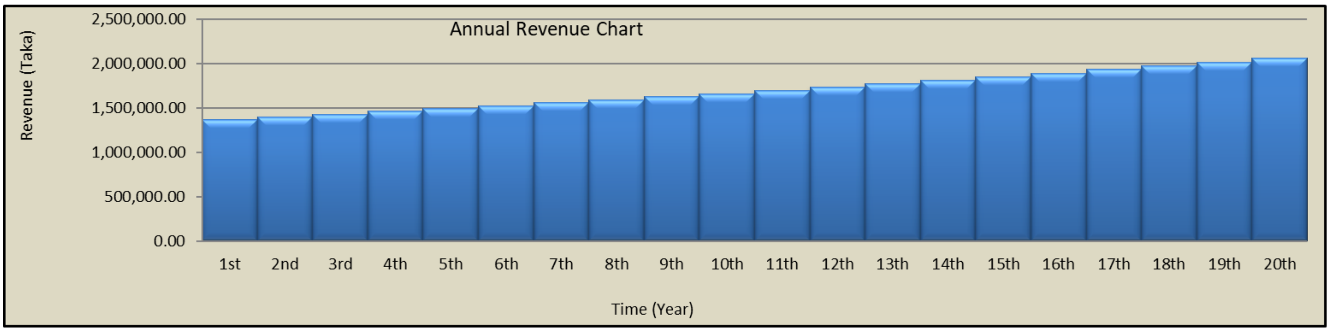
Considering this seasonal solar energy dynamic, optimizing the system's orientation, tilt, and capacity becomes imperative. Aligning the solar panels to capture the maximum sunlight during peak months while factoring in the fluctuations during the monsoon season can enhance the overall efficiency and energy yield of the solar PV installation

Table: Renewable energy (Solar PV) generation status

Year	Total Project Capacity (KWp)	Total Annual Sunlight Time According to NASA (Hour)	Total Plant Efficiency (±5)%	Annual Degradation of Solar Panal (%)	Annual Generation (KWh)	Electricity Bill (Taka)	Annual Revenue (Taka)	Annual Maintenance and Other Cost (Taka)	Annual Profit (Taka)
1st	100	1800	78	2.5	136,890.00	10.00	1,368,900.00	20,000.00	1,348,900.00
2nd				0.8	135,794.88	10.30	1,398,687.26	20,200.00	1,378,487.26
3rd				0.8	134,708.52	10.61	1,429,122.70	20,402.00	1,408,720.70
4th				0.8	133,630.85	10.93	1,460,220.41	20,606.02	1,439,614.39
5th				0.8	132,561.81	11.26	1,491,994.80	20,812.08	1,471,182.72
6th				0.8	131,501.31	11.59	1,524,460.61	21,020.20	1,503,440.41
7th				0.8	130,449.30	11.94	1,557,632.87	21,230.40	1,536,402.47
8th				0.8	129,405.71	12.30	1,591,526.97	21,442.71	1,570,084.26
9th				0.8	128,370.46	12.67	1,626,158.59	21,657.13	1,604,501.46
10th				0.8	127,343.50	13.05	1,661,543.80	21,873.71	1,639,670.10
11th				0.8	126,324.75	13.44	1,697,699.00	22,092.44	1,675,606.55
12th				0.8	125,314.15	13.84	1,734,640.93	22,313.37	1,712,327.56
13th				0.8	124,311.64	14.26	1,772,386.71	22,536.50	1,749,850.21
14th				0.8	123,317.14	14.69	1,810,953.85	22,761.87	1,788,191.98
15th				0.8	122,330.61	15.13	1,850,360.20	22,989.48	1,827,370.72
16th				0.8	121,351.96	15.58	1,890,624.04	23,219.38	1,867,404.66
17th				0.8	120,381.15	16.05	1,931,764.02	23,451.57	1,908,312.45
18th				0.8	119,418.10	16.53	1,973,799.21	23,686.09	1,950,113.12
19th				0.8	118,462.75	17.02	2,016,749.08	23,922.95	1,992,826.13
20th				0.8	117,515.05	17.54	2,060,633.54	24,162.18	2,036,471.36
				Total:	**2,539,383.64**	**--**	**33,849,858.60**	**440,380.08**	**33,409,478.52**

Project Investment_(Taka)	4,800,000.00
Maintenance and Other Cost_(Taka)	440,380.08
Total Investment_(Taka)	5,240,380.08
Total Revenue_(Taka)	33,849,858.60
Net Profit from 20 Years Project Lifetime_(Taka)	28,609,478.52
Per Unit Generation Cost from Solar_(Taka)	2.06
Total Required Space (Approximate)_(Sqr Feet)	10,000
Maximum Panel Weight with Mounting Structure_(Kg/Sqr Feet)	1.5
Maximum Wind Load (Front)_(Kg/Sqr Feet)	50
Maximum Wind Load (Back)_(Kg/Sqr Feet)	22





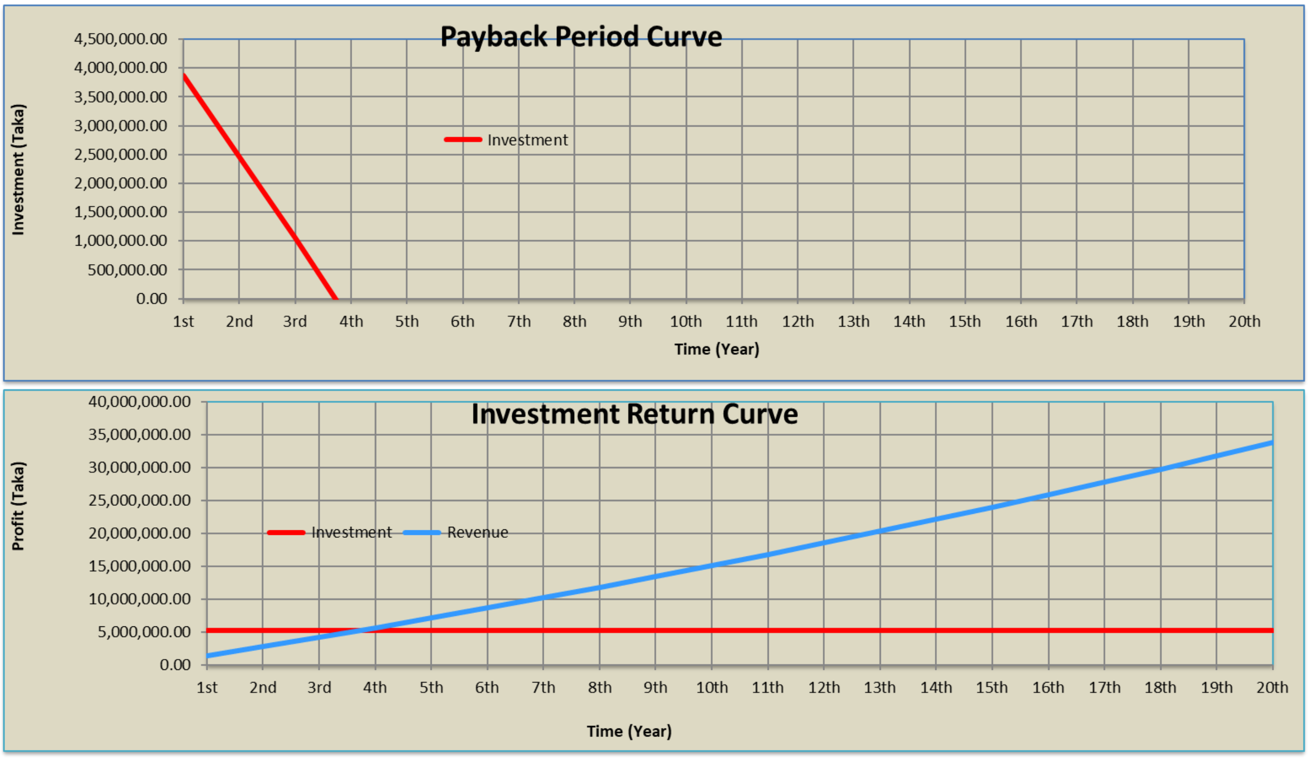


Figure: Cost benefit analysis

SECTION-4

Energy Management, Monitoring and Accounting System

In various industrial sectors, there exists a network of systems delivering specific forms of energy such as gas, diesel, electricity, steam, compressed air, and water circuits. These energy sources serve diverse purposes, including heating, cooling, and powering operational processes. However, the production, distribution, and consumption of these energy media come with escalating costs. As a result, it becomes paramount for all companies to adopt efficient energy utilization and monitoring practices to mitigate these expenses.

Energy costs are not merely on the rise; they are accelerating at an alarming pace. Energy expenditure is often the swiftest growing item in an operational budget and often represents the most significant controllable expense. As companies navigate this landscape, it becomes crucial to comprehensively manage and evaluate their energy usage to curb these escalating costs.

For instance, factors like heating, cooling, compressed air, natural gas, electricity, and steam all contribute significantly to the overall energy expenditure. Consequently, adopting strategies to optimize the production, distribution, and consumption of these energy forms is pivotal. This proactive approach enables companies to navigate the challenges posed by surging energy costs and establish a foundation for sustainable operational practices.

As we delve into the specifics, a thorough analysis of the existing energy monitoring and accounting system is warranted. This examination encompasses aspects such as metering accuracy, meticulous record-keeping, data logging efficiency, and a systematic approach to periodic performance analysis.

The following table provides a detailed overview of these critical components, ensuring a holistic understanding of the energy management framework. By embracing a comprehensive strategy that addresses all facets of energy utilization, companies can navigate the era of accelerating energy costs while maintaining operational efficiency and fiscal prudence.

Table: Energy data-monitoring schedule

Type	Source of Energy	Source of Data	Frequency of Recording	Method of Recording	File Type	Department responsible for file
Primary Energy (Generation Side)	Grid Power	Utility Meter	Monthly	Manual	Utility Bill	Maintenance
	Natural Gas	Utility Meter	Monthly	Manual	Utility Bill	Maintenance
	Diesel	Own meter	daily	Manual	Log Book	Maintenance
Carrier Energy (Distribution Side)	Electricity	Energy meter	hourly	Manual	Log Book	Maintenance
	Steam	Flow meter	hourly	Manual	Log Book	Maintenance
	Compressed Air	No meter	--	--	--	--
	Water	Flow meter	Daily	Manual	Log book	Maintenance

During the course of the energy audit, a noteworthy observation emerged regarding the existing energy monitoring practices. Presently, only the primary energy sources (Electricity, Natural gas, Diesel) feeding into the facility's main incomer are being tracked.

However, a significant gap was identified – the absence of sub-meters to monitor consumption at the individual process, system, and equipment levels. This gap calls for an enhancement in the energy accounting system at the plant, aiming to establish a comprehensive and focused monitoring of energy consumption in correlation with production levels.

It is imperative to address this gap by implementing subsection or area-specific energy meters that measure the consumption of various energy sources, such as electricity, steam, and compressed air. The installation of these meters not only facilitates a granular understanding of energy usage but also empowers the facility to perform comprehensive analyses. This approach enables the identification of significant energy consumption contributors, detection of anomalies, setting energy reduction targets, and evaluating greenhouse gas emissions.

A key aspect of this enhanced monitoring system is the utilization of meaningful Key Performance Indicators (KPIs). By constantly monitoring the system and evaluating it against these KPIs, operators, supervisors, and management remain well-informed. This not only enables a proactive approach to energy management but also fosters an environment of constructive engagement.

The implementation of an Energy Monitoring and Management System holds multiple advantages. It provides a comprehensive view of the facility's energy consumption landscape, thereby enabling informed decisions aimed at reducing energy usage. This enhanced understanding can lead to the optimization of utility contracts, compliance with energy regulations, and improved operation and maintenance practices.

Ultimately, the integration of such a system facilitates intelligent analysis of energy data, resulting in minimized utility energy consumption, cost savings, and a reduced carbon footprint. This aligns seamlessly with the broader goals of sustainability and responsible resource utilization, contributing to both economic and environmental well-being.

Recommended energy management actions

IRIS FABRIC LIMITED energy management improvement steps:

Policy: Create a concise energy policy signed by CEO, displayed prominently in the factory. Develop an Action Plan with identified improvements and update it every six months.

Organizing: Incorporate energy efficiency in board meetings, with energy team reporting progress to management. Highlight energy benefits for company profitability.

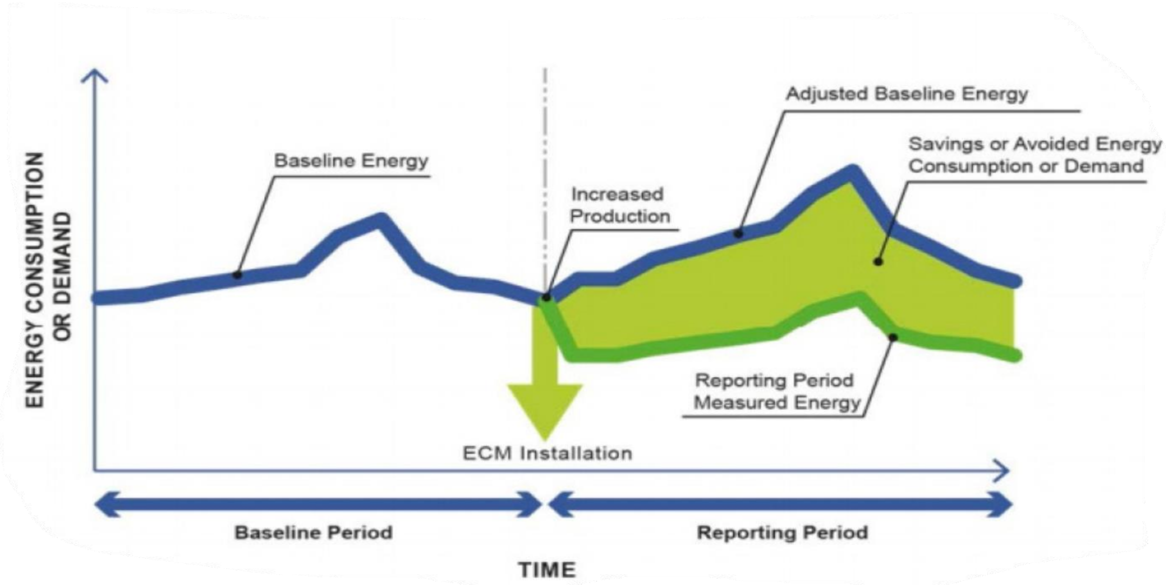
Motivation: Provide feedback on energy savings to all staff. Promote energy efficiency in meetings with the workforce. Develop awareness through counseling, training, and encouraging energy-saving practices.

Information Systems: Produce informational leaflets or a green notice board detailing energy savings progress. Implement individual metering systems for specific utilities and production sections.

Marketing: Promote energy efficiency to staff and customers, enhancing the company's green image. Encourage participation in energy-saving practices and showcase green credentials to clients.

Investment: Reinvest financial savings into more energy-saving measures. Actively invest in low-cost opportunities and use resulting profits to fund medium to high-cost energy-saving initiatives.

SECTION-5
Measurement And Verification Method For ENMS



When companies invest in energy efficiency, they seek clear insights into the savings achieved and their sustainability. This necessitates accurate measurement and a replicable methodology, known as a measurement and verification (M&V) protocol. Developing an M&V Plan is pivotal for accurate savings determination and serves as the foundation for verification. Thorough planning guarantees the availability of data required for accurate savings calculation post-implementation, all within a feasible budget.

An M&V plan encompasses:

ECM Description: Clearly outlining the Energy Conservation Measure (ECM) and its intended outcomes.

Boundary Identification: Defining the scope of the savings determination, outlining which elements are under consideration.

Base Year Context: Documenting the facility's conditions during the base year and the corresponding energy consumption data.

Base Year Adjustments: Identifying any planned changes to base year conditions, such as alterations in nighttime temperatures.

Post-Retrofit Period: Specifying the timeframe for the post-retrofit period, which could be as short as a brief test following the implementation of an ECM.

In essence, a well-crafted M&V plan lays the groundwork for accurate assessment, ensuring that energy savings are quantified reliably and with confidence.

Types of M & V methods

Four primary types of Measurement and Verification (M&V) methods are utilized: Here's an overview of the M&V methods, their savings calculation approaches, and typical applications:

Partially Measured Retrofit Isolation:

Savings Calculation Method: Savings are determined by measuring the energy use of the system(s) where an ECM is applied, separate from the rest of the facility. Some parameters may be stipulated if the potential error's impact isn't significant. ECM design and installation should ensure stipulated values fairly represent actual values.

Typical Application: For instance, in a lighting retrofit, power draw is periodically measured. Operating hours are assumed to be slightly longer than store open hours.

Retrofit Isolation:

Savings Calculation Method: Savings are determined by measuring the energy use of the systems to which the ECM is applied, separate from the rest of the facility. Short-term or continuous measurements are taken during the post-retrofit period.

Typical Application: An example is applying controls to regulate load on a constant-speed pump with a variable speed drive. Electricity use is measured by a kWh meter on the pump motor's supply. The meter is in place throughout the post-retrofit period.

3. Whole Facility:

Savings Calculation Method: Savings are determined by analyzing utility meter data for the entire facility or using multifaceted energy management programs. Short-term or continuous measurements are taken at the whole facility level throughout the post-retrofit period.

Typical Application: This method is suitable for analyzing broad energy-saving initiatives that affect numerous systems within a building. For instance, measuring energy use through simple regression analysis and comparison of utility billing data.

Calibrated Simulation:

Savings Calculation Method: Savings are determined using energy simulation, where components or the entire facility are simulated and calibrated to actual performance measurements. Simulation routines must effectively model real energy performance within the facility.

Typical Application: Calibrated simulation is ideal when no base year data are available. It involves creating a model that's calibrated using post-retrofit period utility data, requiring skilled simulation expertise.

These M&V methods offer diverse approaches for evaluating energy savings in different contexts. The choice of method depends on the nature of the project, the availability of data, and the desired level of accuracy.

SECTION-6

Suggested Best Operating Practices (BOPs)

Best Operating Practices (BOPs) refer to a set of guidelines and procedures that are considered the most effective and efficient way to operate a particular system, process, or piece of equipment. BOPs are designed to ensure safety, optimize performance, and minimize the risk of errors or accidents. The specific BOPs you should follow will depend on the context, industry, and equipment or process in question. However, here are some general principles and suggested BOPs that can be applied across various domains:

BOP 1: Boiler maintenance

Boiler maintenance is vital for energy efficiency and operational reliability. To minimize energy consumption and unexpected downtime, a systematic approach is essential. Assign responsibility for maintaining and documenting daily, weekly, monthly, and annual tasks with checklists. Regular maintenance includes inspections, cleaning heat transfer surfaces, and maintaining insulation.

Performing a tune-up helps identify off-design equipment performance and site-specific constraints before optimizing boiler efficiency. For negative-draft boilers, check for air leakage using smoke, a flame, or ultrasonic equipment. Address high oxygen readings from air leaks that lead to fuel waste. Use ultrasonic probes to detect steam leaks in water-tube boilers. For boilers with storage tanks, shut off water supply and observe water levels to identify leaks. Ensure low-water cutoff controls are functional before testing.

BOP 2: Air-to-Fuel ratio

Efficient operation of any combustion equipment is highly dependent on a proper air-to fuel ratio. Due to the mechanics of combustion, it is necessary to provide more air than would be required to provide exactly the right quantity of oxygen (O_2) to burn all the fuel without any O_2 left over. Because air is comprised of approximately 21 percent O_2 and 79 percent nitrogen (N_2), in delivering the right amount of O_2, nearly four times as much N_2 is also delivered. Nitrogen absorbs heat and carries it out the stack, resulting in a loss to the system. Minimizing excess air, consistent with complete combustion, minimizes this heat loss. Complete carbon combustion forms carbon dioxide (CO2) as heat is released. Incomplete combustion forms carbon monoxide (CO) and less than one-third as much heat is released. CO is an un-burned combustible and, in the stack gas, an efficiency loss to the system. Most systems will also display a calculated combustion efficiency value. Even with continuous monitoring of the flue gas, non-optimum air-to- fuel ratios may result due to air leaking in upstream of the analyzer; infrequent or incorrect analyzer calibration; insufficient combustion air supply at full load; or an analyzer placed at a non-representative location.

BOP 3: Combustion uniformity

Complete combustion at efficient excess air levels requires the fuel and air to be uniformly mixed throughout the primary combustion zone. In multi-burner gas boilers, non-uniform combustion can result if the fuel and air are not evenly distributed due to a malfunctioning burner. The natural tendency when encountering noticeable CO levels is to raise excess air levels for the whole boiler, causing the other burners to operate at unnecessarily high O2 levels. Uniform combustion can quite often be achieved by simple adjustments to the air. Register or damper settings. In other cases, further diagnostic testing is required. Considerable insight into combustion uniformity can be obtained by mapping the O2 profile at the economizer exit. Systems exist that will automatically measure and map O2 concentrations on a continuous basis.

BOP 4: Blowdown management

Blowdown is essential for maintaining low concentrations of dissolved solids in the water (skimming blowdown) or removing solids that have settled out of the water (bottom blowdown). Both practices result in unavoidable energy losses as hot water is wasted to the drain, and a balance must be maintained between acceptable results and energy losses. Skimming blowdown is best used as a continuous process; bottom blowdown is best done periodically as several short blowdowns. Continuous blowdown makes the use of heat recovery devices more feasible.

BOP 5: Load management

When multiple boilers serve many loads, it is important to manage them as efficiently as possible. Individual boilers achieve maximum efficiency over a specific firing range. Units with high excess air requirements or significant radiation losses at low loads will have peak efficiency at a high load. Boilers with constant excess air levels and small radiation losses over the load range will exhibit peak efficiency at a lower load. Efficiencies should be determined over the full range of firing rates. More efficient boilers should be brought on line first as loads increase, and less efficient units should be taken off-line first as loads drop. Where possible, scheduling of loads can help achieve optimum system performance.

BOP 6: Reduce steam pressure

To the extent practical, steam should be generated at the lowest pressure that will meet the highest-pressure demand. Less fuel is required and lower stack temperatures result, improving efficiency. Savings may be as much as 1 or 2 percent, but actual savings depend on the starting pressure and the pressure reduction that is realized.

BOP 7: Maintenance of insulation

The primary mechanism for heat loss through the skin of an uninsulated boiler is radiant heat loss. The higher the temperature of the boiler skin (insulated or not), the greater the radiant heat loss to the surroundings. The first inch of insulation reduces heat loss by about 90 percent. Each additional inch obviously will have much less impact. One rule of thumb is that any surface above 120°F should be insulated, including boiler surfaces, steam or condensate piping and fittings.

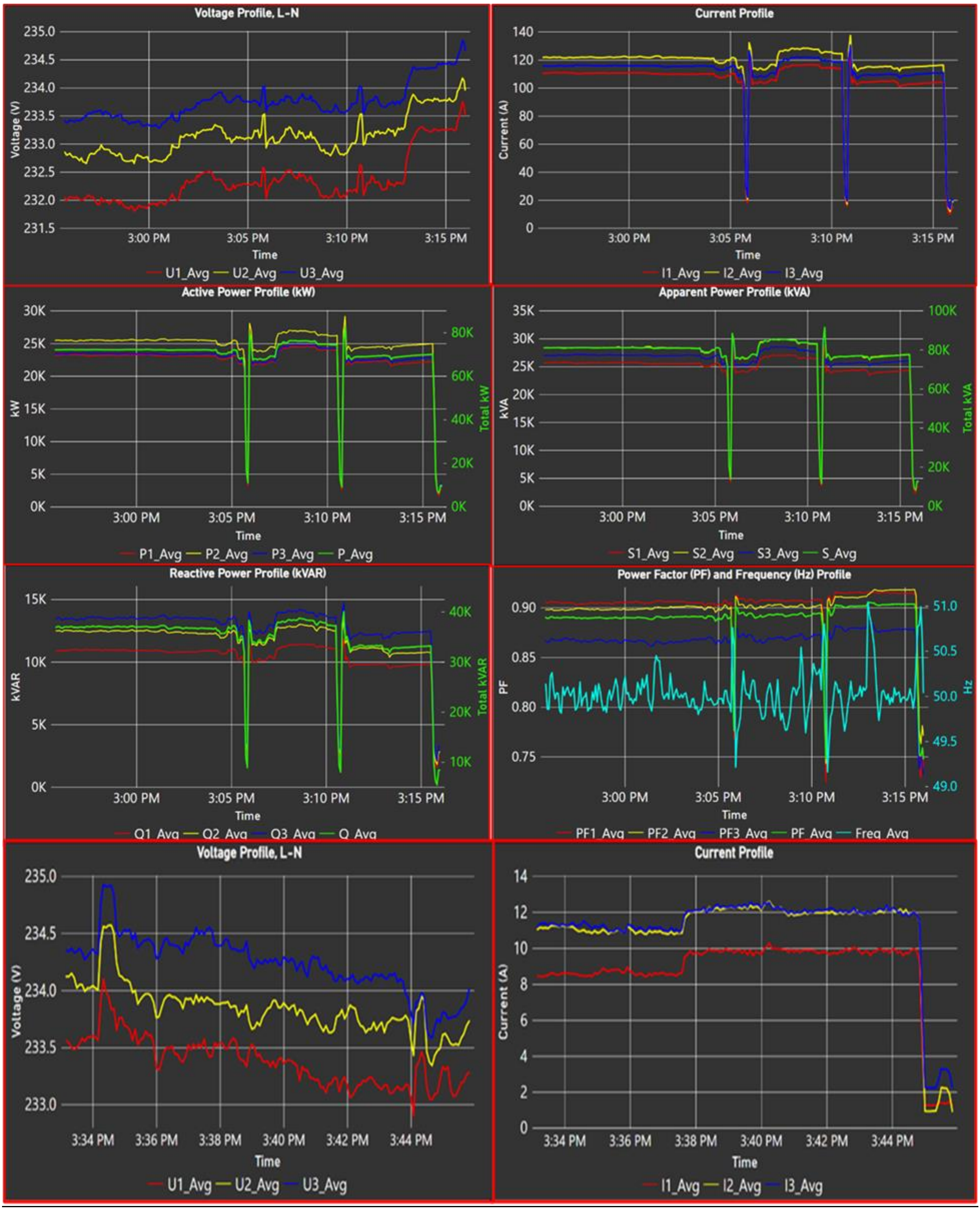
BOP 8: For Compressed Air System

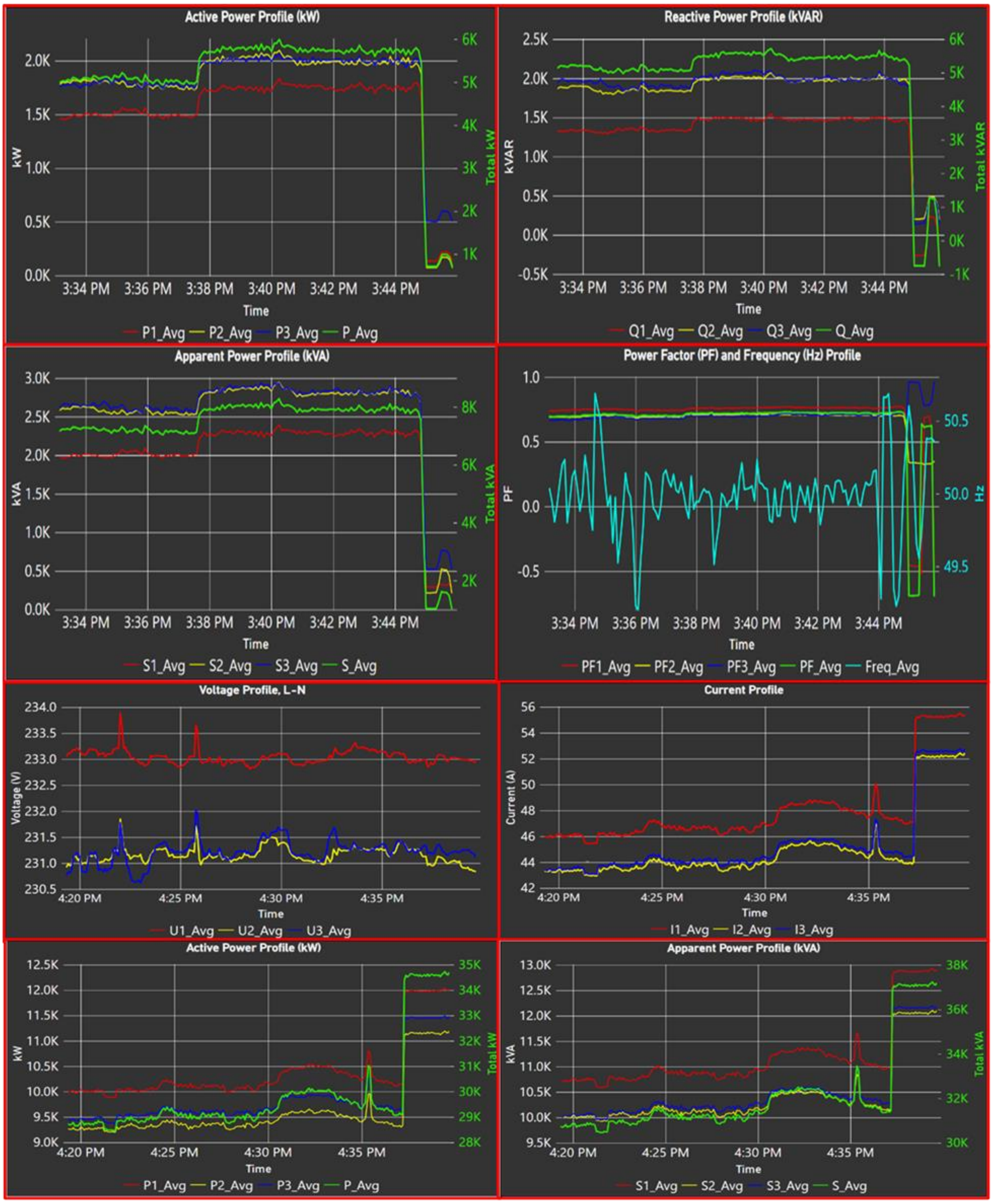
- Ensure air intake to compressor is not warm and humid by locating compressors in well ventilated area or by drawing cold air from outside. Every 4°C rise in air inlet temperature will increase power consumption by 1 percent
- Clean air-inlet filters regularly. Compressor efficiency will be reduced by 2 percent for every 250 mm WC pressure drop across the filter.
- Keep compressor valves in good condition by removing and inspecting once every six months. Worn- out valves can reduce compressor efficiency by as much as 50 percent.
- Install manometers across the filter and monitor the pressure drop as a guide to replacement of element.
- Minimize low-load compressor operation; if air demand is less than 50 percent of compressor capacity, consider change over to a smaller compressor or reduce compressor speed appropriately (by reducing motor pulley size) in case of belt driven compressors.
- Consider the use of regenerative air dryers, which uses the heat of compressed air to remove moisture.
- Fouled inter-coolers reduce compressor efficiency & cause more water condensation in air receivers & distribution lines resulting in increased corrosion. Periodic cleaning of intercoolers must be ensured.
- Compressor free air delivery test (FAD) must be done periodically to check the present operating capacity against its design capacity and corrective steps must be taken if required.
- If more than one compressor is feeding to a common header, compressors must be operated in such a way that only one small compressor should handle the load variations whereas other compressors will operate at full load.

- The possibility of heat recovery from hot compressed air to generate hot air or water for process application must be economically analyzed in case of large compressors.
- Consideration should be given to two-stage or multistage compressor as it consumes less power for the same air output than a single stage compressor.
- If pressure requirements for processes are widely different (e.g., 3 bar to 7 bar), it is advisable to have two separate compressed air systems.
- Reduce compressor delivery pressure, wherever possible, to save energy.
- Provide extra air receivers at points of high cyclic-air demand which permits operation without extra compressor capacity.
- Retrofit with variable speed drives in big compressors, say over 100 kW, to eliminate the unloaded' running condition altogether.
- Keep the minimum possible range between load and unload pressure settings. • Automatic timer-controlled drain traps waste compressed air every time the valve opens. So, frequency of drainage should be optimized.
- Check air compressor logs regularly for abnormal readings, especially motor current cooling water flow and temperature, inter-stage and discharge pressures and temperatures and compressor load-cycle.
- Compressed air leakage of 40 – 50 percent is not uncommon. Carry out periodic leak tests to estimate the quantity of leakage.
- Install equipment interlocked solenoid cut-off valves in the air system so that air supply to a machine can be switched off when not in use.
- Present energy prices justify liberal designs of pipeline sizes to reduce pressure drops.
- Compressed air piping layout should be made preferably as a ring main to provide desired pressures for all users.
- A smaller dedicated compressor can be installed at load point, located far off from the central compressor house, instead of supplying air through lengthy pipelines.
- All pneumatic equipment should be properly lubricated, which will reduce friction, prevent wear of seals and other rubber parts thus preventing energy wastage due to excessive air consumption or leakage.
- Misuse of compressed air such as for body cleaning, agitation, general floor cleaning, and other similar applications must be discouraged in order to save compressed air and energy.
- Pneumatic equipment should not be operated above the recommended operating pressure as this not only wastes energy bus can also lead to excessive wear of equipment's components which leads to further energy wastage.
- Pneumatic transport can be replaced by mechanical system as the former consumed about 8 times more energy. Highest possibility of energy savings is by reducing compressed air use.
- Pneumatic tools such as drill and grinders consume about 20 times more energy than motor driven tools. Hence, they have to be used efficiently. Wherever possible, they should be replaced with electrically operated tools.
- Where possible welding is a good practice and should be preferred over threaded connections.
- On account of high pressure drop, ball or plug or gate valves are preferable over globe valves in compressed air lines.

Appendices

APPENDIX-1: POWER QUALITY PROFILE SAMPLE




Active Power Profile (kW)
kW
Total kW
Time
P1_Avg P2_Avg P3_Avg P_Avg
Reactive Power Profile (kVAR)
kVAR
Total kVAR
Time
Q1_Avg Q2_Avg Q3_Avg Q_Avg
Apparent Power Profile (kVA)
kVA
Total kVA
Time
S1_Avg S2_Avg S3_Avg S_Avg
Power Factor (PF) and Frequency (Hz) Profile
PF
Hz
Time
PF1_Avg PF2_Avg PF3_Avg PF_Avg Freq_Avg
Voltage Profile, L-N
Voltage (V)
Time
U1_Avg U2_Avg U3_Avg
Current Profile
Current (A)
Time
I1_Avg I2_Avg I3_Avg
Active Power Profile (kW)
kW
Total kW
Time
P1_Avg P2_Avg P3_Avg P_Avg
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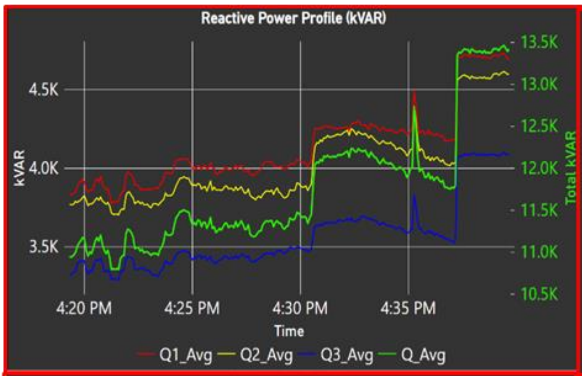
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4.0K
3.5K
13.5K
13.0K
12.5K
12.0K
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11.0K
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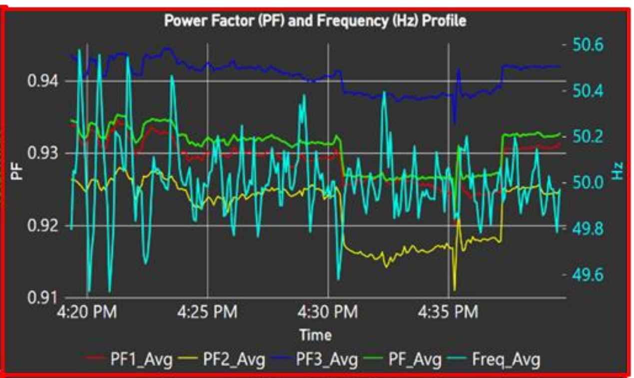
Q3_Avg
Q_Avg


Power Factor (PF) and Frequency (Hz) Profile
PF
Hz
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0.93
0.92
0.91
50.6
50.4
50.2
50.0
49.8
49.6
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4:25 PM
4:30 PM
4:35 PM
Time
PF1_Avg
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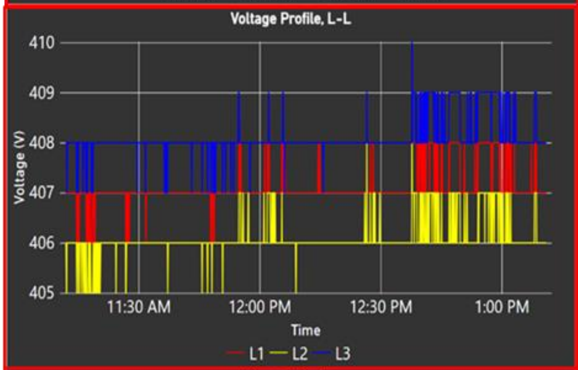
PF_Avg
Freq_Avg


Voltage Profile, L-L
Voltage (V)
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409
408
407
406
405
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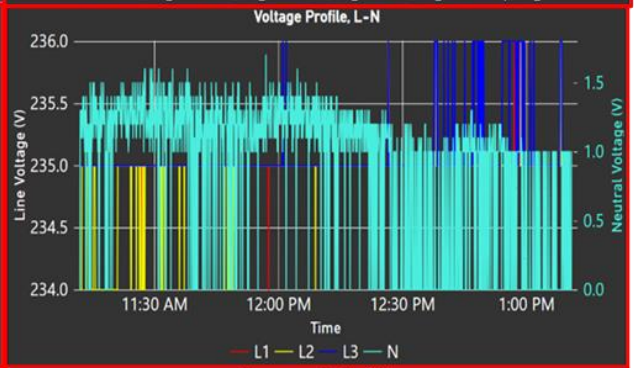
12:00 PM
12:30 PM
1:00 PM
Time
L1
L2
L3


Voltage Profile, L-N
Line Voltage (V)
Neutral Voltage (V)
236.0
235.5
235.0
234.5
234.0
1.5
1.0
0.5
0.0
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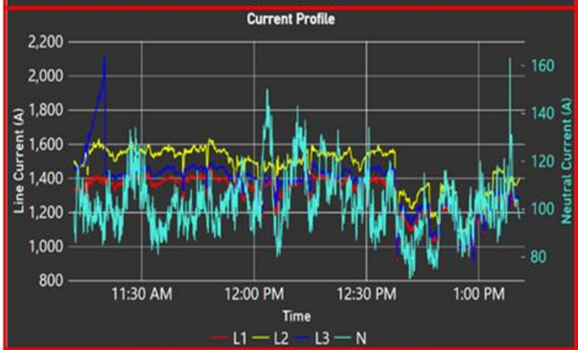
12:00 PM
12:30 PM
1:00 PM
Time
L1
L2
L3
N


Current Profile
Line Current (A)
Neutral Current (A)
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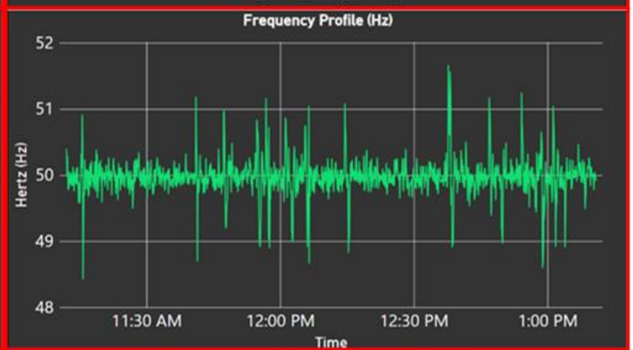
2,000
1,800
1,600
1,400
1,200
1,000
800
160
140
120
100
80
11:30 AM
12:00 PM
12:30 PM
1:00 PM
Time
L1
L2
L3
N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Hertz (Hz)
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50
49
48
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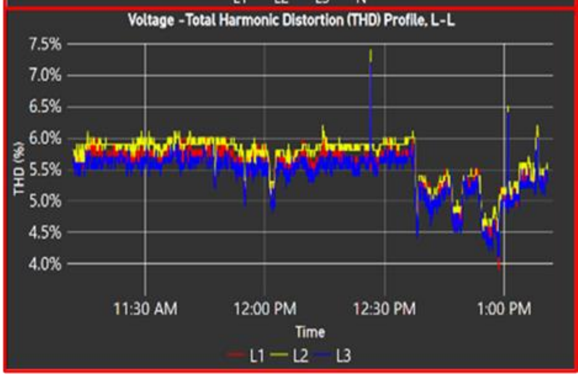
12:00 PM
12:30 PM
1:00 PM
Time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THD (%)
7.5%
7.0%
6.5%
6.0%
5.5%
5.0%
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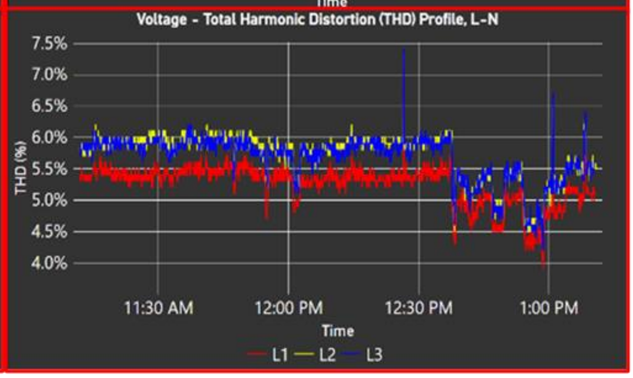
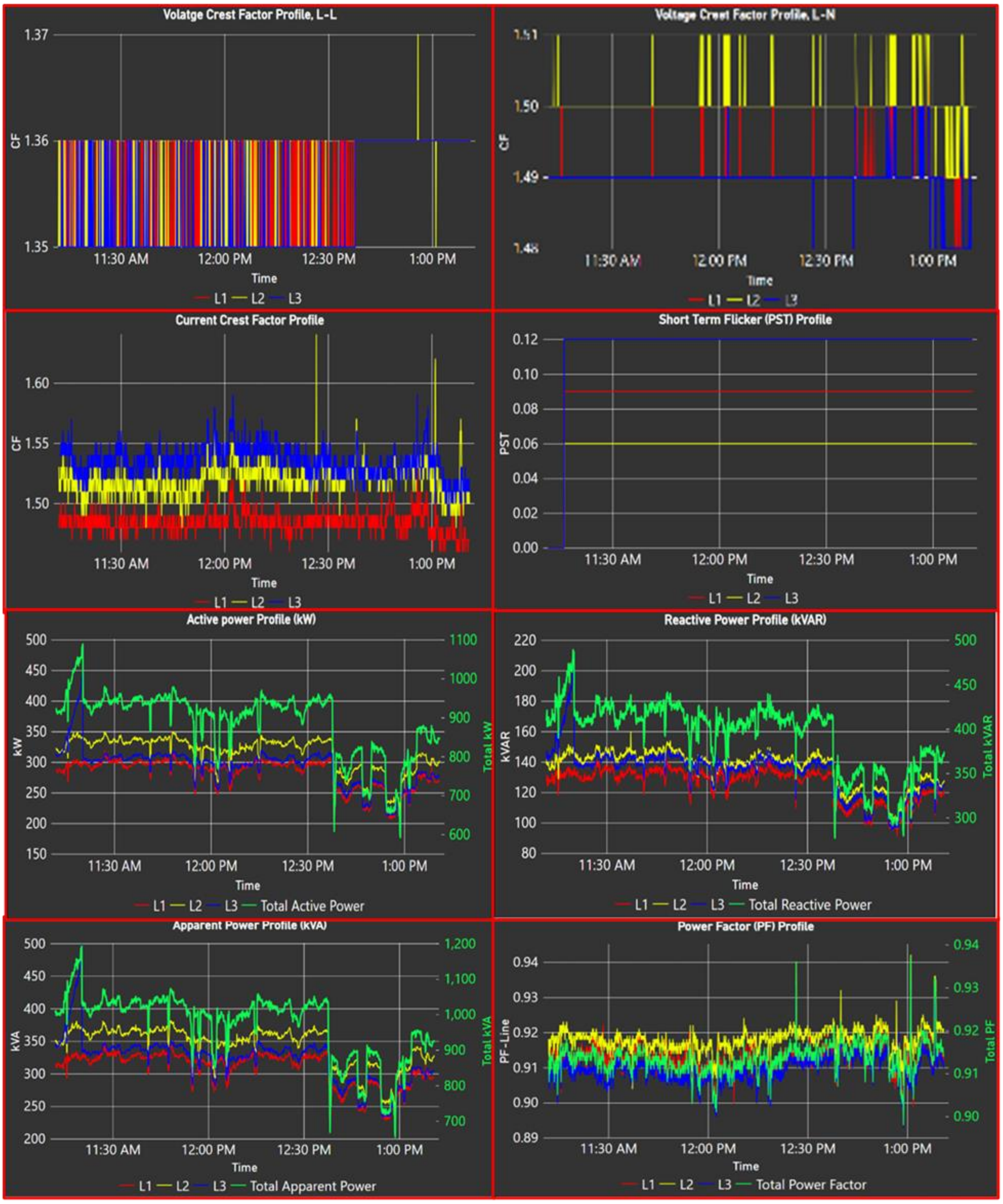
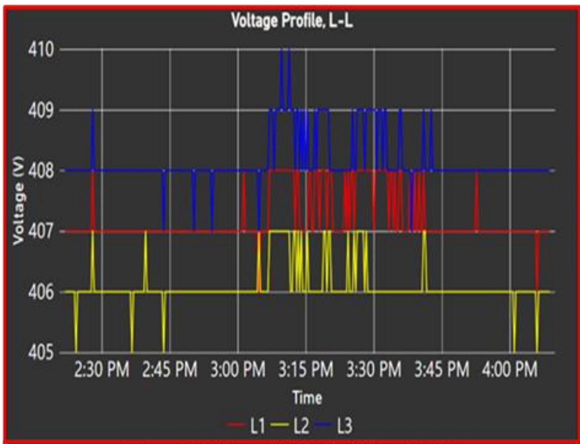
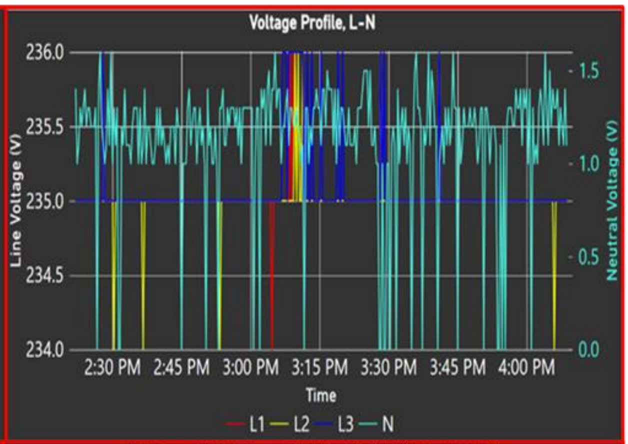
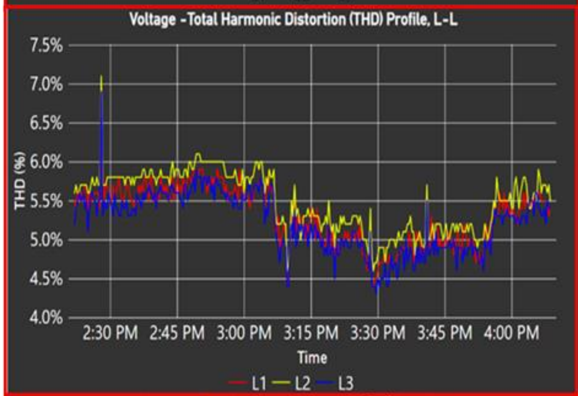
4.0%
11:30 AM
12:00 PM
12:30 PM
1:00 PM
Time
L1
L2
L3

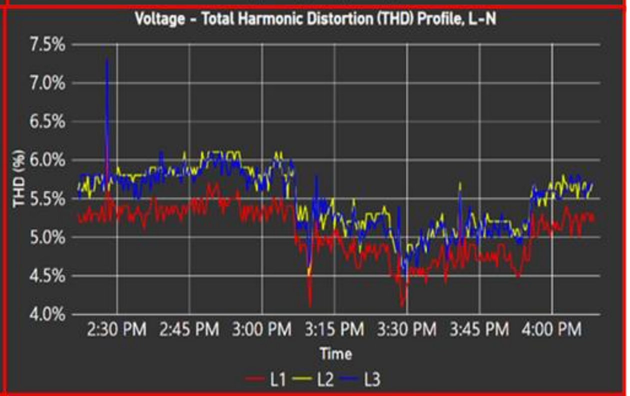

Voltage - Total Harmonic Distortion (THD) Profile, L-N
THD (%)
7.5%
7.0%
6.5%
6.0%
5.5%
5.0%
4.5%
4.0%
11:30 AM
12:00 PM
12:30 PM
1:00 PM
Time
L1
L2
L3

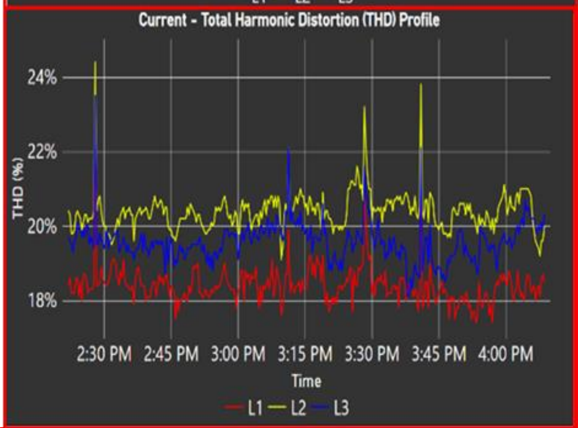

Volatge Crest Factor Profile, L-L
CF
Time
L1 L2 L3
Voltage Crest Factor Profile, L-N
CF
Time
L1 L2 L3
Current Crest Factor Profile
CF
Time
L1 L2 L3
Short Term Flicker (PST) Profile
PST
Time
L1 L2 L3
Active power Profile (kW)
kW
Total kW
Time
L1 L2 L3 Total Active Power
Reactive Power Profile (kVAR)
kVAR
Total kVAR
Time
L1 L2 L3 Total Reactive Power
Apparent Power Profile (kVA)
kVA
Total kVA
Time
L1 L2 L3 Total Apparent Power
Power Factor (PF) Profile
PF-Line
Total PF
Time
L1 L2 L3 Total Power Factor

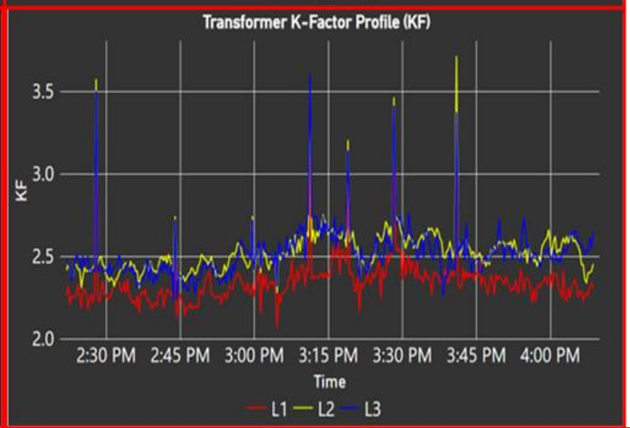

Voltage Profile, L-L
Voltage (V)
410
409
408
407
406
405
2:30 PM 2:45 PM 3:00 PM 3:15 PM 3:30 PM 3:45 PM 4:00 PM
Time
L1 L2 L3

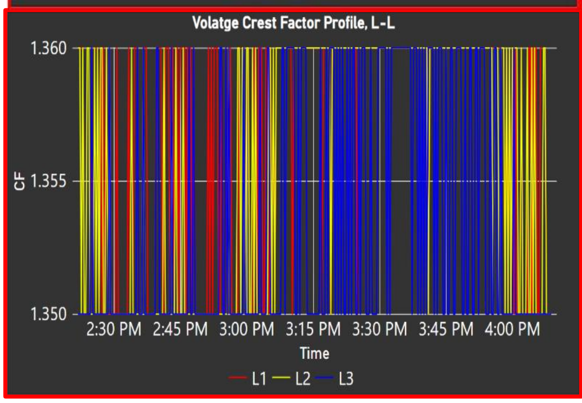

Voltage Profile, L-N
Line Voltage (V)
236.0
235.5
235.0
234.5
234.0
Neutral Voltage (V)
1.5
1.0
0.5
0.0
2:30 PM 2:45 PM 3:00 PM 3:15 PM 3:30 PM 3:45 PM 4:00 PM
Time
L1 L2 L3 N

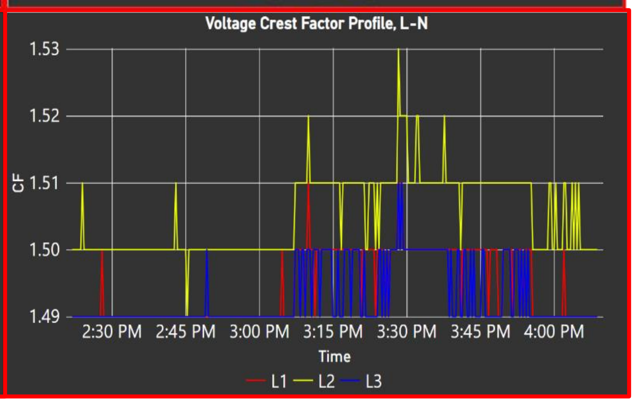

Voltage -Total Harmonic Distortion (THD) Profile, L-L
THD (%)
7.5%
7.0%
6.5%
6.0%
5.5%
5.0%
4.5%
4.0%
2:30 PM 2:45 PM 3:00 PM 3:15 PM 3:30 PM 3:45 PM 4:00 PM
Time
L1 L2 L3


Voltage - Total Harmonic Distortion (THD) Profile, L-N
THD (%)
7.5%
7.0%
6.5%
6.0%
5.5%
5.0%
4.5%
4.0%
2:30 PM 2:45 PM 3:00 PM 3:15 PM 3:30 PM 3:45 PM 4:00 PM
Time
L1 L2 L3

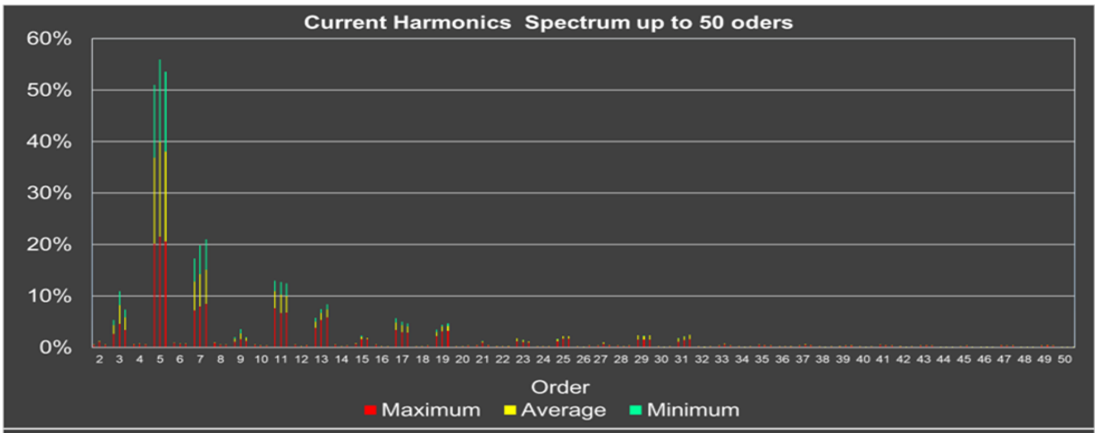

Current - Total Harmonic Distortion (THD) Profile
THD (%)
24%
22%
20%
18%
2:30 PM 2:45 PM 3:00 PM 3:15 PM 3:30 PM 3:45 PM 4:00 PM
Time
L1 L2 L3

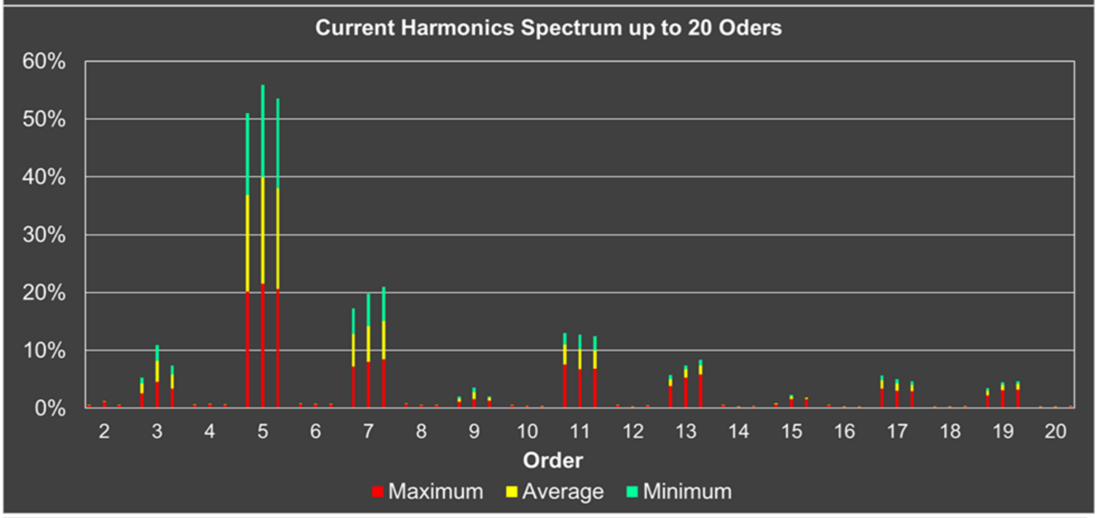

Transformer K-Factor Profile (KF)
KF
3.5
3.0
2.5
2.0
2:30 PM 2:45 PM 3:00 PM 3:15 PM 3:30 PM 3:45 PM 4:00 PM
Time
L1 L2 L3

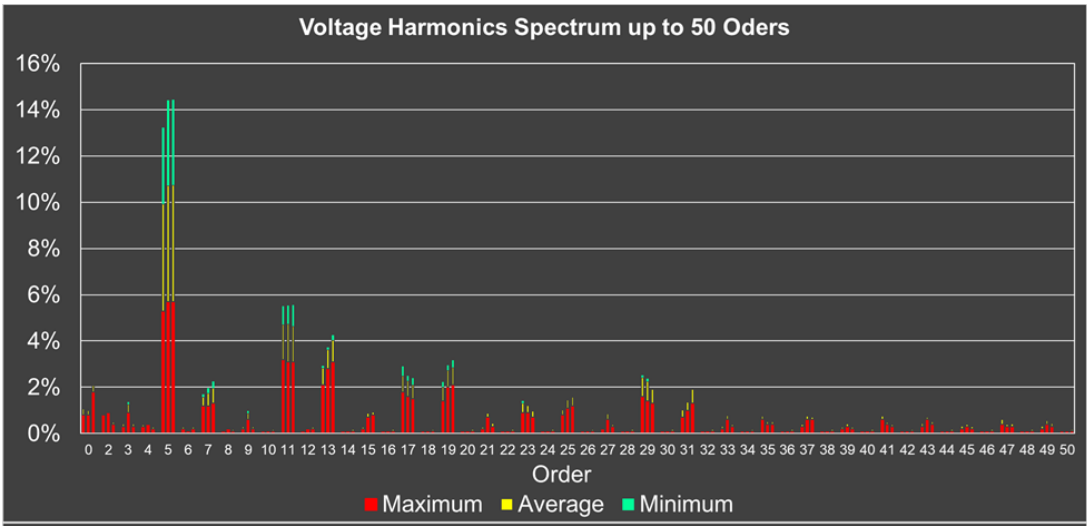

Volatge Crest Factor Profile, L-L
CF
1.360
1.355
1.350
2:30 PM 2:45 PM 3:00 PM 3:15 PM 3:30 PM 3:45 PM 4:00 PM
Time
L1 L2 L3

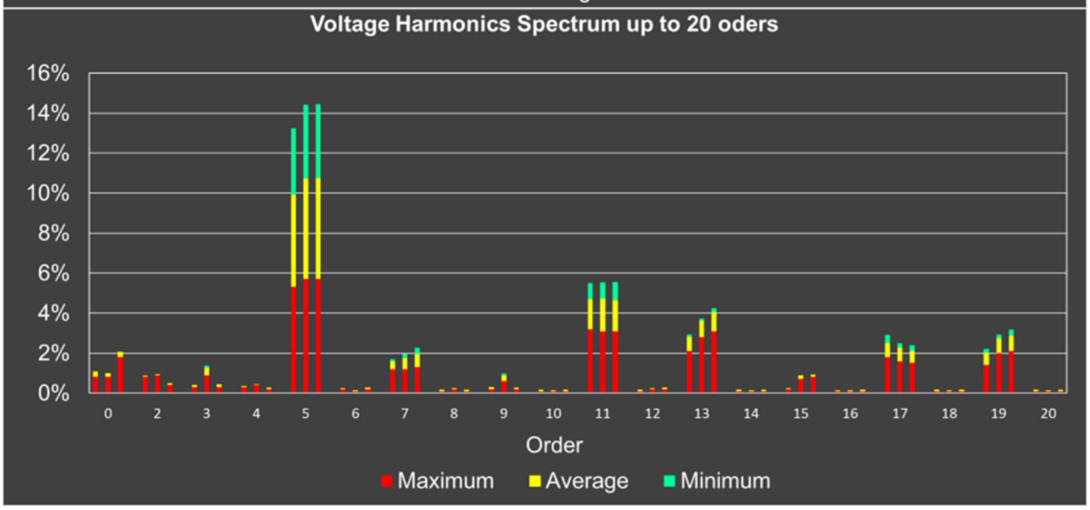

Voltage Crest Factor Profile, L-N
CF
1.53
1.52
1.51
1.50
1.49
2:30 PM 2:45 PM 3:00 PM 3:15 PM 3:30 PM 3:45 PM 4:00 PM
Time
L1 L2 L3

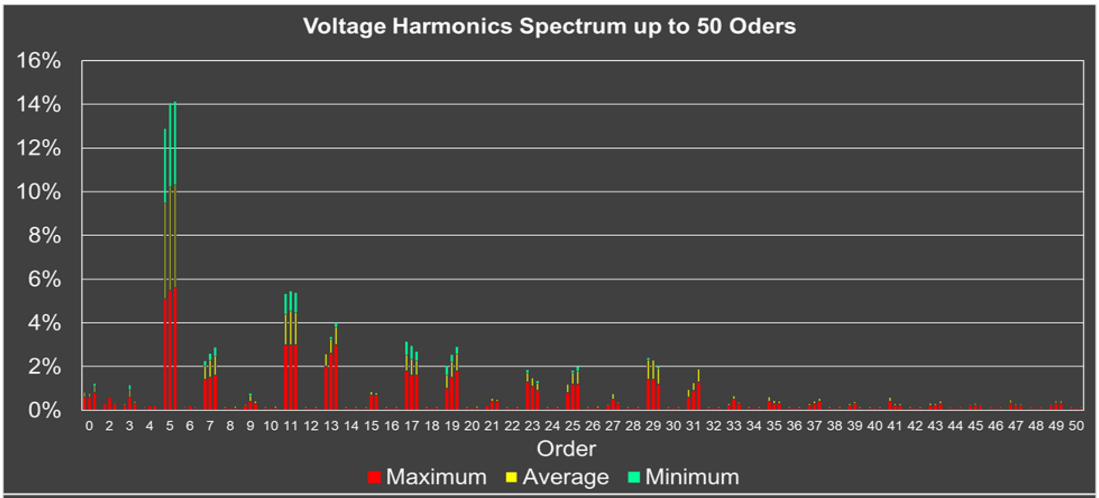

Short Term Flicker (PST) Profile
PST
0.12
0.11
0.10
0.09
0.08
0.07
0.06
2:30 PM 2:45 PM 3:00 PM 3:15 PM 3:30 PM 3:45 PM 4:00 PM
Time
L1 L2 L3
Current Crest Factor Profile
CF
1.65
1.60
1.55
1.50
2:30 PM 2:45 PM 3:00 PM 3:15 PM 3:30 PM 3:45 PM 4:00 PM
Time
L1 L2 L3
Active power Profile (kW)
kW
350
300
250
200
Total kW
1000
900
800
700
600
2:30 PM 2:45 PM 3:00 PM 3:15 PM 3:30 PM 3:45 PM 4:00 PM
Time
L1 L2 L3 Total Active Power
Reactive Power Profile (kVAR)
kVAR
150
140
130
120
110
100
90
80
Total kVAR
400
350
300
250
2:30 PM 2:45 PM 3:00 PM 3:15 PM 3:30 PM 3:45 PM 4:00 PM
Time
L1 L2 L3 Total Reactive Power
Apparent Power Profile (kVA)
kVA
350
300
250
200
Total kVA
1,100
1,000
900
800
700
600
2:30 PM 2:45 PM 3:00 PM 3:15 PM 3:30 PM 3:45 PM 4:00 PM
Time
L1 L2 L3 Total Apparent Power
Power Factor (PF) Profile
PF-Line
0.94
0.93
0.92
0.91
0.90
0.89
Total PF
0.94
0.93
0.92
0.91
0.90
2:30 PM 2:45 PM 3:00 PM 3:15 PM 3:30 PM 3:45 PM 4:00 PM
Time
L1 L2 L3 Total Power Factor
Voltage Unbalance Profile (Vunb)
Unbalance Voltage (%)
0.6%
0.5%
0.4%
0.3%
0.2%
0.1%
2:30 PM 2:45 PM 3:00 PM 3:15 PM 3:30 PM 3:45 PM 4:00 PM
Time
Current Unbalance Profile (Aunb)
Unbalance Current (%)
4.5%
4.0%
3.5%
3.0%
2.5%
2:30 PM 2:45 PM 3:00 PM 3:15 PM 3:30 PM 3:45 PM 4:00 PM
Time

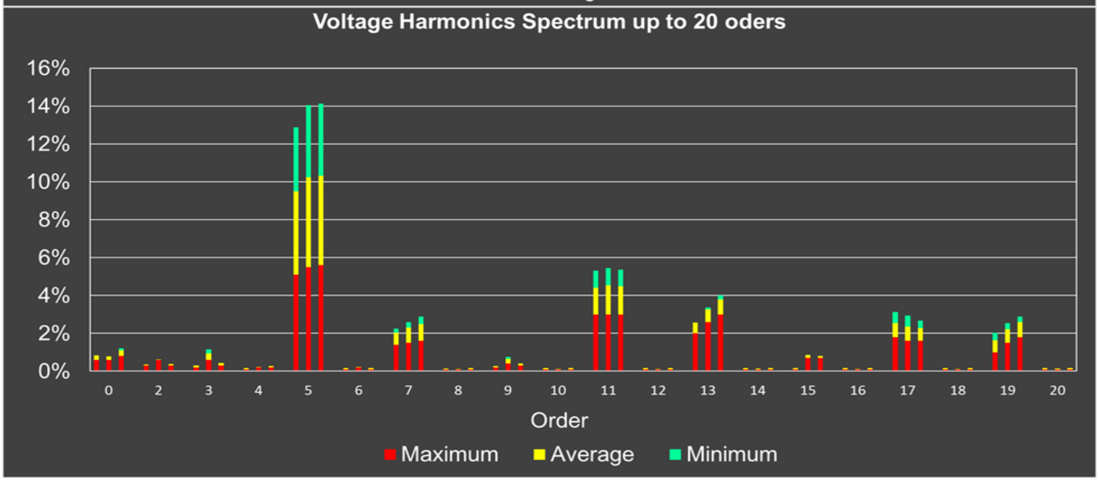

Current Harmonics Spectrum up to 50 oders
60%
50%
40%
30%
20%
10%
0%
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
Order
Maximum
Average
Minimum

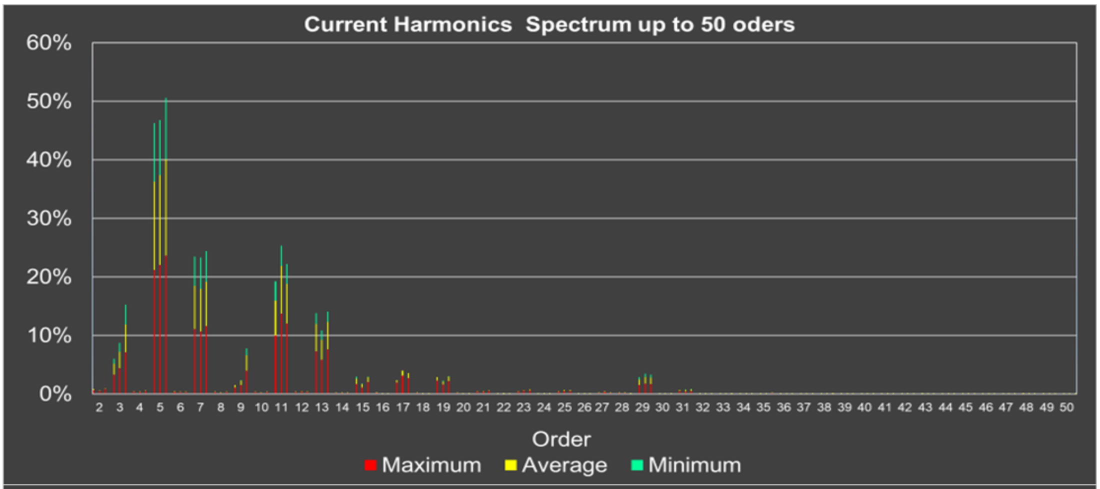

Current Harmonics Spectrum up to 20 Oders
60%
50%
40%
30%
20%
10%
0%
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Order
Maximum
Average
Minimum

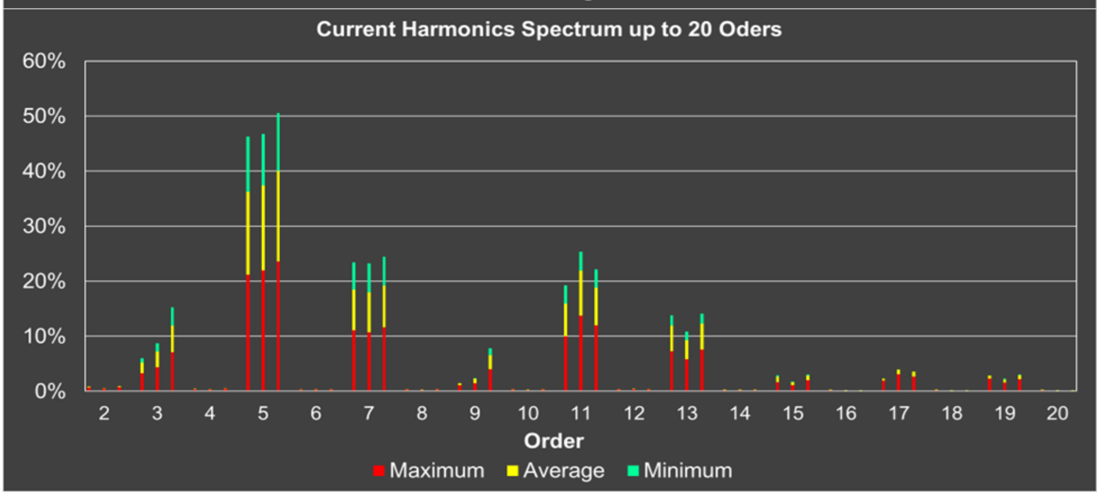

Voltage Harmonics Spectrum up to 50 Oders
16%
14%
12%
10%
8%
6%
4%
2%
0%
0 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
Order
Maximum
Average
Minimum


Voltage Harmonics Spectrum up to 20 oders
16%
14%
12%
10%
8%
6%
4%
2%
0%
0 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Order
Maximum
Average
Minimum


Voltage Harmonics Spectrum up to 50 Oders
16%
14%
12%
10%
8%
6%
4%
2%
0%
0 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
Order
Maximum
Average
Minimum


Voltage Harmonics Spectrum up to 20 oders
16%
14%
12%
10%
8%
6%
4%
2%
0%
0 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Order
Maximum
Average
Minimum


Current Harmonics Spectrum up to 50 oders
60%
50%
40%
30%
20%
10%
0%
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50
Order
Maximum
Average
Minimum


Current Harmonics Spectrum up to 20 Oders
60%
50%
40%
30%
20%
10%
0%
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Order
Maximum
Average
Minimum

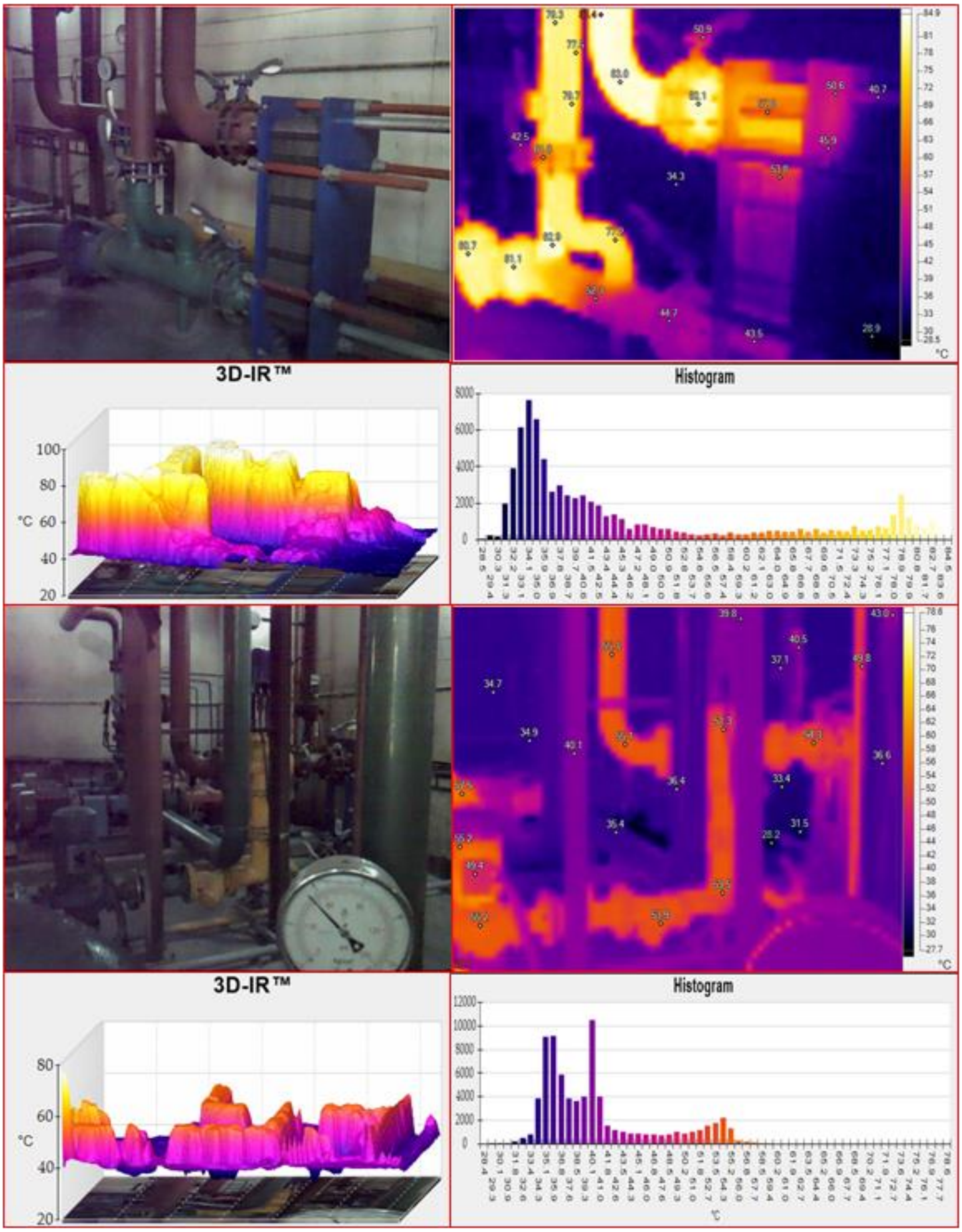
Parameters	Range	L1	L2	L3	N	Total
Voltage (V) (L-N)	Max	236	236	236	1.7	--
	Avg	235.01	234.93	235.07	0.88	--
	Min	234	234	235	0	--
Voltage Unbalance (%)	Max	0.5				
	Avg	0.24				
	Min	0.1				
Current (A)	Max	1480	1630	2120	163	--
	Avg	1310.81	1457.4	1369.3	102.14	--
	Min	900	977	901	71	--
Current Unbalance (%)	Max	13.7				
	Avg	3.55				
	Min	1.5				
Voltage (THD) (%) (L-L)	Max	7.1	7.4	7.2	--	--
	Avg	5.53	5.67	5.42	--	--
	Min	3.9	4.3	4.1	--	--
Voltage (THD) (%) (L-N)	Max	6.8	7.3	7.4	--	--
	Avg	5.24	5.71	5.67	--	--
	Min	3.9	4.3	4.2	--	--
Current (THD) (%)	Max	23.2	24.6	23.8	--	--
	Avg	18.23	20.35	19.35	--	--
	Min	16	18.3	17.9	--	--
Active Power (KW)	Max	318.1	349.5	453.3	--	1089
	Avg	281.19	314.3	292.91	--	888.4
	Min	190.8	209.3	191	--	591.8
Apparent Power (KVA)	Max	347	381.5	498.9	--	1193
	Avg	307.9	342.19	321.93	--	972.01
	Min	212	230.2	212.3	--	654.5
Reactive Power (KVAR)	Max	142.8	159.9	208.3	--	489.2
	Avg	125.4	135.28	133.54	--	394.22
	Min	90.22	93.8	92.65	--	277
Power Factor	Max	0.94	0.94	0.93	--	0.94
	Avg	0.91	0.92	0.91	--	0.91
	Min	0.9	0.9	0.89	--	0.9
Frequency (Hz)	Max	51.66				
	Avg	49.97				
	Min	48.43				
Voltage Crest factor (L-L)	Max	1.36	1.37	1.36	--	--
	Avg	1.36	1.35	1.35	--	--
	Min	1.35	1.35	1.35	--	--
Voltage Crest factor (L-N)	Max	1.51	1.51	1.5	--	--
	Avg	1.49	1.5	1.49	--	--
	Min	1.48	1.49	1.48	--	--
Current Crest factor	Max	1.58	1.64	1.59	--	--
	Avg	1.48	1.52	1.53	--	--
	Min	1.46	1.48	1.49	--	--
Transformer K-Factor	Max	3.4	3.65	3.64	--	--
	Avg	2.25	2.46	2.4	--	--
	Min	2.06	2.16	1.98	--	--
Short Term Flicker	Max	0.09	0.06	0.12	--	--
	Avg	0.09	0.06	0.12	--	--
	Min	0	0	0	--	--
COS ϕ	Max	0.96	0.97	0.96	--	--
	Avg	0.93	0.94	0.93	--	--
	Min	0.91	0.93	0.91	--	--
Tan ϕ	Max	0.49	0.47	0.5	--	--
	Avg	0.45	0.43	0.46	--	--
	Min	0.37	0.35	0.38	--	--

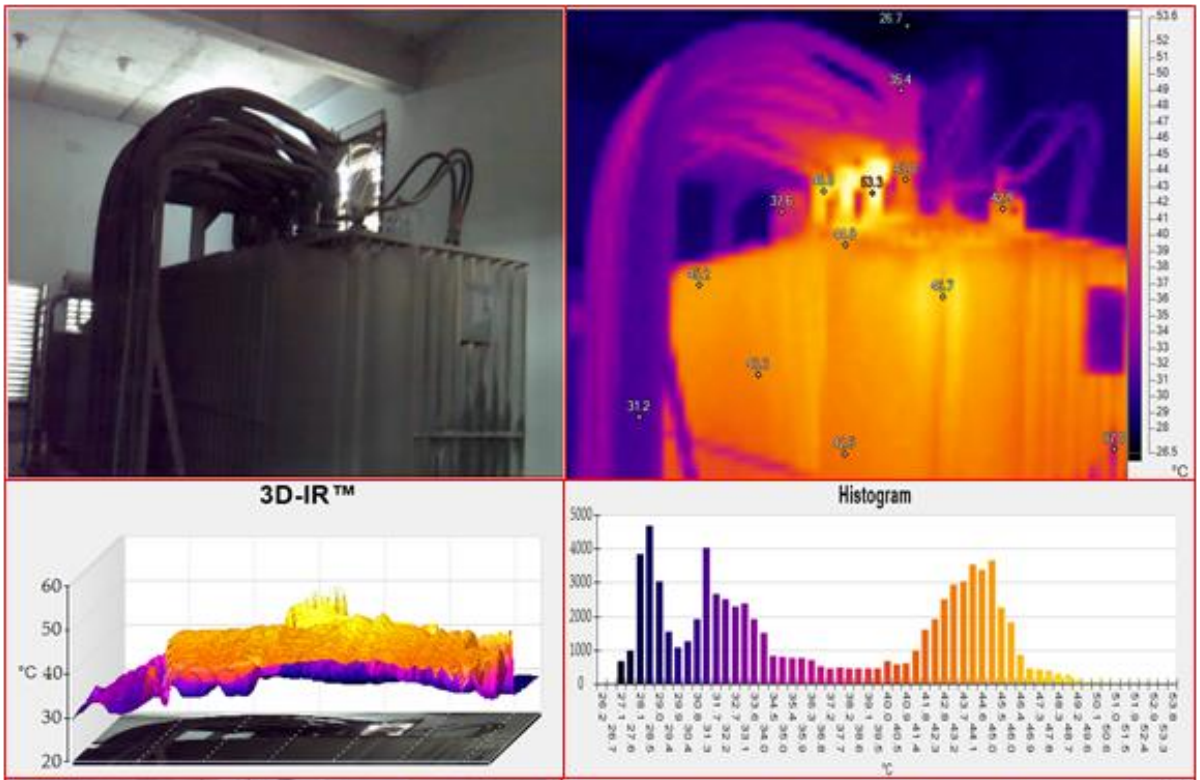
Parameters	Range	L1	L2	L3	N	Total
Voltage (V) (L-N)	Max	236	236	236	1.6	--
	Avg	235.02	235.01	235.07	1.13	--
	Min	234	234	235	0	--
Voltage Unbalance (%)	Max	0.6				
	Avg	0.26				
	Min	0.10				
Current (A)	Max	1430	1620	1500	128	--
	Avg	1207.55	1357.18	1247.2	92.64	--
	Min	847	974	879	61	--
Current Unbalance (%)	Max	4.7				
	Avg	3.5				
	Min	2.4				
Voltage (THD) (%) (L-L)	Max	6.9	7.1	6.9	--	--
	Avg	5.31	5.48	5.21	--	--
	Min	4.4	4.6	4.3	--	--
Voltage (THD) (%) (L-N)	Max	6.6	7.1	7.3	--	--
	Avg	5.06	5.5	5.46	--	--
	Min	4.1	4.5	4.5	--	--
Current (THD) (%)	Max	22.4	24.4	23.5	22.4	--
	Avg	18.4	20.39	19.58	18.4	--
	Min	17.4	19.1	18.1	17.4	--
Active Power (KW)	Max	308.5	349.5	320.7	--	977.5
	Avg	258.48	292.1	266.69	--	817.26
	Min	178.5	207.4	185.6	--	571.5
Apparent Power (KVA)	Max	336.8	379.5	352.1	--	1066
	Avg	283.78	318.7	293.31	--	895.8
	Min	199.4	229.2	207	--	635.6
Reactive Power (KVAR)	Max	137.2	148	146	--	427.5
	Avg	117.08	127.42	122.08	--	366.57
	Min	82.21	89.71	86.61	--	258.8
Power Factor	Max	0.94	0.94	0.94	--	0.94
	Avg	0.91	0.92	0.91	--	0.91
	Min	0.89	0.9	0.9	--	0.9
Frequency (Hz)	Max	51.02				
	Avg	49.97				
	Min	49.07				
Crest factor Voltage (L-L)	Max	1.36	1.36	1.36	--	--
	Avg	1.36	1.36	1.35	--	--
	Min	1.35	1.35	1.35	--	--
Crest factor Voltage (L-N)	Max	1.51	1.53	1.51	--	--
	Avg	1.49	1.5	1.49	--	--
	Min	1.49	1.49	1.49	--	--
Crest factor current	Max	1.58	1.66	1.6	--	--
	Avg	1.5	1.53	1.54	--	--
	Min	1.47	1.5	1.51	--	--
Transformer K-Factor	Max	3.32	3.71	3.6	--	--
	Avg	2.34	2.53	2.52	--	--
	Min	2.07	2.28	2.24	--	--
Short Term Flicker	Max	0.09	0.06	0.12	--	--
	Avg	0.09	0.06	0.12	--	--
	Min	0.09	0.06	0.12	--	--
COS ϕ	Max	0.96	0.97	0.97	--	--
	Avg	0.93	0.94	0.93	--	--
	Min	0.91	0.93	0.92	--	--
Tan ϕ	Max	0.5	0.47	0.49	--	--
	Avg	0.45	0.44	0.46	--	--
	Min	0.37	0.36	0.36	--	--

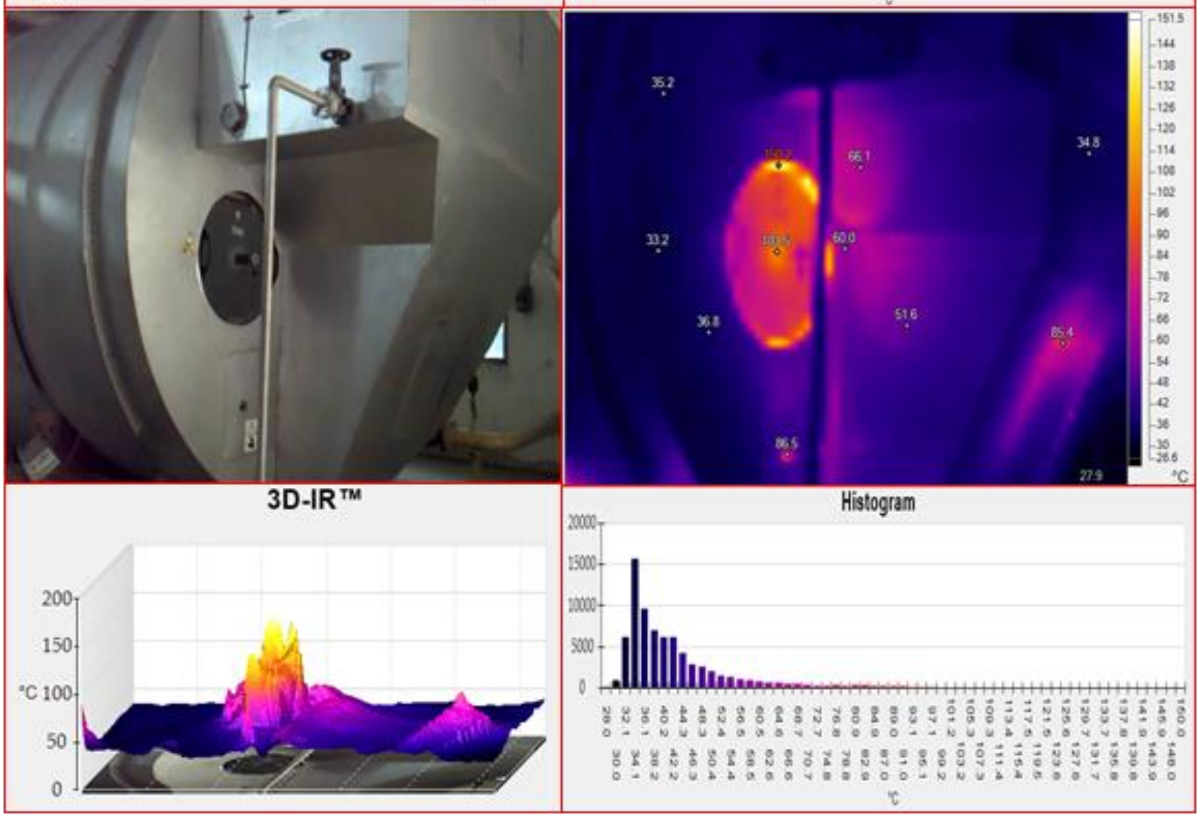
Harmonics Profile									
Voltage Profile (V)					Current Profile (A)				
Oders	Range	R	Y	B	Oders	Range	R	Y	B
0th	Max	0.80%	0.28%	0.00%	2nd	Max	0.50%	0.10%	0.00%
	Avg	0.80%	0.19%	0.00%		Avg	1.10%	0.14%	0.00%
	Min	1.80%	0.28%	0.00%		Min	0.50%	0.08%	0.00%
2nd	Max	0.80%	0.06%	0.00%	3rd	Max	2.60%	1.70%	1.00%
	Avg	0.90%	0.04%	0.00%		Avg	4.60%	3.62%	2.70%
	Min	0.40%	0.08%	0.00%		Min	3.40%	2.40%	1.60%
3rd	Max	0.30%	0.12%	0.00%	4th	Max	0.60%	0.06%	0.00%
	Avg	0.90%	0.36%	0.10%		Avg	0.70%	0.08%	0.00%
	Min	0.30%	0.13%	0.00%		Min	0.60%	0.07%	0.00%
4th	Max	0.30%	0.06%	0.00%	5th	Max	20.20%	16.68%	14.10%
	Avg	0.40%	0.04%	0.00%		Avg	21.50%	18.43%	16.00%
	Min	0.20%	0.07%	0.00%		Min	20.60%	17.47%	15.50%
5th	Max	5.30%	4.63%	3.30%	6th	Max	0.80%	0.06%	0.00%
	Avg	5.70%	5.01%	3.70%		Avg	0.70%	0.07%	0.00%
	Min	5.70%	5.04%	3.70%		Min	0.70%	0.08%	0.00%
6th	Max	0.20%	0.06%	0.00%	7th	Max	7.20%	5.60%	4.50%
	Avg	0.10%	0.04%	0.00%		Avg	8.00%	6.20%	5.60%
	Min	0.20%	0.08%	0.00%		Min	8.50%	6.57%	5.90%
7th	Max	1.20%	0.39%	0.10%	8th	Max	0.80%	0.06%	0.00%
	Avg	1.20%	0.56%	0.20%		Avg	0.50%	0.06%	0.00%
	Min	1.30%	0.65%	0.30%		Min	0.50%	0.07%	0.00%
8th	Max	0.10%	0.06%	0.00%	9th	Max	1.10%	0.59%	0.30%
	Avg	0.20%	0.04%	0.00%		Avg	1.60%	1.14%	0.80%
	Min	0.10%	0.08%	0.00%		Min	1.30%	0.55%	0.20%
9th	Max	0.20%	0.11%	0.00%	10th	Max	0.50%	0.05%	0.00%
	Avg	0.60%	0.28%	0.10%		Avg	0.30%	0.06%	0.00%
	Min	0.20%	0.09%	0.00%		Min	0.30%	0.07%	0.00%
10th	Max	0.10%	0.06%	0.00%	11th	Max	7.60%	3.36%	2.00%
	Avg	0.10%	0.04%	0.00%		Avg	6.70%	3.51%	2.50%
	Min	0.10%	0.07%	0.00%		Min	6.80%	3.22%	2.40%
11th	Max	3.20%	1.51%	0.80%	12th	Max	0.50%	0.05%	0.00%
	Avg	3.10%	1.63%	0.80%		Avg	0.20%	0.06%	0.00%
	Min	3.10%	1.54%	0.90%		Min	0.40%	0.07%	0.00%
12th	Max	0.10%	0.06%	0.00%	13th	Max	3.80%	1.23%	0.70%
	Avg	0.20%	0.04%	0.00%		Avg	5.30%	1.42%	0.70%
	Min	0.20%	0.07%	0.00%		Min	5.80%	1.59%	1.00%
13th	Max	2.10%	0.73%	0.10%	14th	Max	0.50%	0.05%	0.00%
	Avg	2.80%	0.83%	0.10%		Avg	0.20%	0.06%	0.00%
	Min	3.10%	0.94%	0.20%		Min	0.30%	0.07%	0.00%
14th	Max	0.10%	0.06%	0.00%	15th	Max	0.70%	0.15%	0.00%
	Avg	0.10%	0.04%	0.00%		Avg	1.60%	0.47%	0.20%
	Min	0.10%	0.08%	0.00%		Min	1.60%	0.23%	0.00%
15th	Max	0.20%	0.06%	0.00%	16th	Max	0.50%	0.05%	0.00%
	Avg	0.70%	0.18%	0.00%		Avg	0.20%	0.06%	0.00%
	Min	0.80%	0.12%	0.00%		Min	0.20%	0.07%	0.00%
16th	Max	0.10%	0.06%	0.00%	17th	Max	3.40%	1.43%	0.80%
	Avg	0.10%	0.04%	0.00%		Avg	3.00%	1.30%	0.70%
	Min	0.10%	0.07%	0.00%		Min	2.90%	1.14%	0.60%
17th	Max	1.80%	0.70%	0.40%	18th	Max	0.20%	0.05%	0.00%
	Avg	1.60%	0.69%	0.20%		Avg	0.20%	0.06%	0.00%
	Min	1.50%	0.60%	0.30%		Min	0.30%	0.07%	0.00%
18th	Max	0.10%	0.06%	0.00%	19th	Max	2.20%	0.79%	0.50%
	Avg	0.10%	0.04%	0.00%		Avg	3.10%	0.93%	0.40%
	Min	0.10%	0.07%	0.00%		Min	3.20%	0.98%	0.50%
19th	Max	1.40%	0.62%	0.20%	20th	Max	0.20%	0.05%	0.00%
	Avg	2.00%	0.74%	0.20%		Avg	0.20%	0.05%	0.00%
	Min	2.10%	0.76%	0.30%		Min	0.30%	0.07%	0.00%
20th	Max	0.10%	0.06%	0.00%	21st	Max	0.40%	0.90%	0.40%
	Avg	0.10%	0.04%	0.00%		Avg	0.10%	0.28%	0.13%
	Min	0.10%	0.07%	0.00%		Min	0.00%	0.10%	0.00%

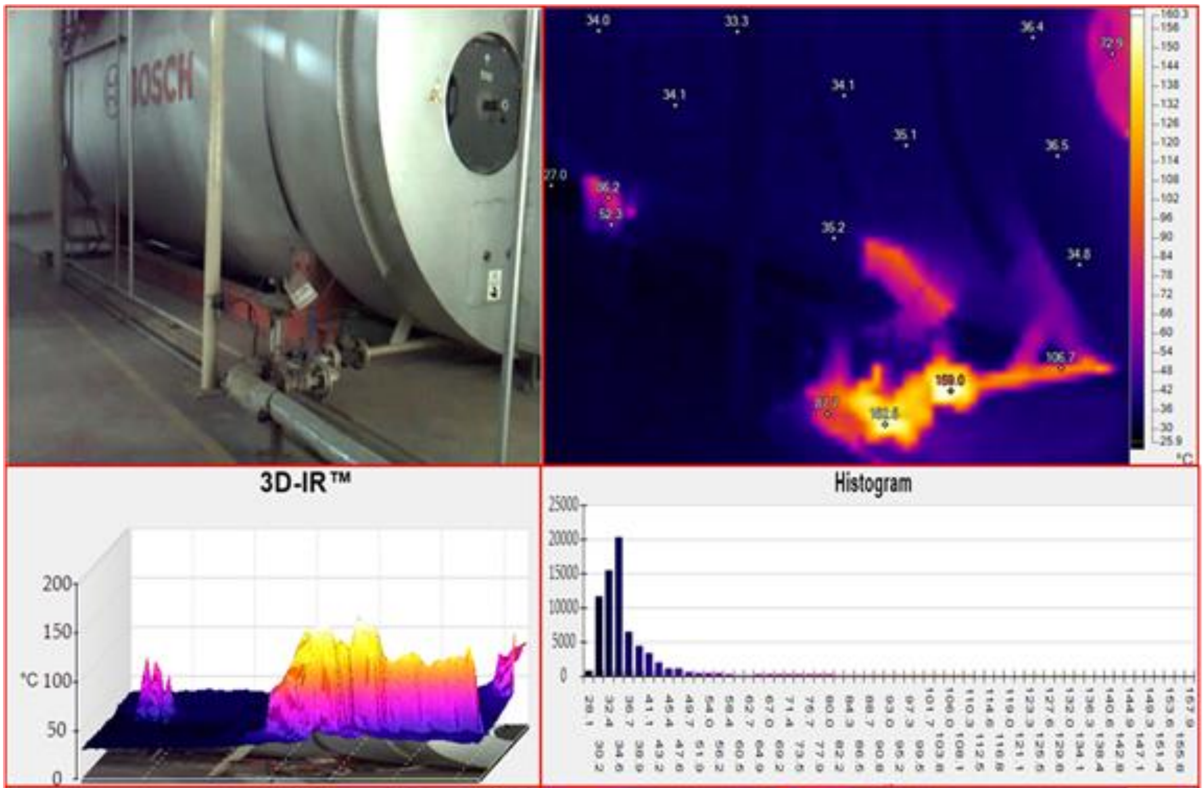
Harmonics Profile									
Voltage Profile (V)					Current Profile (A)				
Oders	Range	R	Y	B	Oders	Range	R	Y	B
0th	Max	0.60%	0.23%	0.00%	2nd	Max	0.70%	0.11%	0.00%
	Avg	0.60%	0.19%	0.00%		Avg	0.70%	0.14%	0.00%
	Min	0.80%	0.31%	0.10%		Min	0.30%	0.07%	0.00%
2nd	Max	0.30%	0.06%	0.00%	3rd	Max	2.20%	1.69%	1.00%
	Avg	0.60%	0.04%	0.00%		Avg	4.80%	3.59%	2.90%
	Min	0.30%	0.08%	0.00%		Min	4.20%	2.72%	1.80%
3rd	Max	0.20%	0.11%	0.00%	4th	Max	0.60%	0.06%	0.00%
	Avg	0.60%	0.35%	0.20%		Avg	0.40%	0.07%	0.00%
	Min	0.30%	0.13%	0.00%		Min	0.30%	0.06%	0.00%
4th	Max	0.10%	0.07%	0.00%	5th	Max	19.40%	16.61%	15.30%
	Avg	0.20%	0.03%	0.00%		Avg	21.20%	18.27%	16.60%
	Min	0.20%	0.07%	0.00%		Min	20.20%	17.32%	15.50%
5th	Max	5.10%	4.38%	3.40%	6th	Max	0.40%	0.06%	0.00%
	Avg	5.50%	4.75%	3.80%		Avg	0.50%	0.06%	0.00%
	Min	5.60%	4.73%	3.80%		Min	0.70%	0.07%	0.00%
6th	Max	0.10%	0.07%	0.00%	7th	Max	8.60%	6.21%	5.20%
	Avg	0.20%	0.03%	0.00%		Avg	8.80%	6.67%	5.80%
	Min	0.10%	0.07%	0.00%		Min	9.40%	7.26%	6.10%
7th	Max	1.40%	0.64%	0.20%	8th	Max	0.20%	0.05%	0.00%
	Avg	1.50%	0.80%	0.30%		Avg	0.20%	0.04%	0.00%
	Min	1.60%	0.88%	0.40%		Min	0.20%	0.07%	0.00%
8th	Max	0.10%	0.06%	0.00%	9th	Max	0.90%	0.57%	0.20%
	Avg	0.10%	0.03%	0.00%		Avg	1.60%	1.13%	0.80%
	Min	0.10%	0.08%	0.00%		Min	1.50%	0.75%	0.30%
9th	Max	0.20%	0.09%	0.00%	10th	Max	0.30%	0.05%	0.00%
	Avg	0.40%	0.25%	0.10%		Avg	0.30%	0.05%	0.00%
	Min	0.30%	0.12%	0.00%		Min	0.20%	0.07%	0.00%
10th	Max	0.10%	0.07%	0.00%	11th	Max	7.30%	3.34%	2.80%
	Avg	0.10%	0.03%	0.00%		Avg	6.60%	3.58%	3.20%
	Min	0.10%	0.08%	0.00%		Min	6.70%	3.26%	2.70%
11th	Max	3.00%	1.41%	0.90%	12th	Max	0.20%	0.05%	0.00%
	Avg	3.00%	1.55%	0.90%		Avg	0.20%	0.05%	0.00%
	Min	3.00%	1.48%	0.90%		Min	0.50%	0.07%	0.00%
12th	Max	0.10%	0.06%	0.00%	13th	Max	3.70%	1.28%	1.00%
	Avg	0.10%	0.03%	0.00%		Avg	4.90%	1.39%	0.90%
	Min	0.10%	0.07%	0.00%		Min	5.20%	1.66%	1.10%
13th	Max	2.00%	0.58%	0.00%	14th	Max	0.20%	0.06%	0.00%
	Avg	2.60%	0.66%	0.10%		Avg	0.20%	0.04%	0.00%
	Min	3.00%	0.80%	0.20%		Min	0.20%	0.06%	0.00%
14th	Max	0.10%	0.06%	0.00%	15th	Max	0.50%	0.18%	0.00%
	Avg	0.10%	0.03%	0.00%		Avg	1.40%	0.46%	0.20%
	Min	0.10%	0.07%	0.00%		Min	1.30%	0.25%	0.10%
15th	Max	0.10%	0.07%	0.00%	16th	Max	0.20%	0.05%	0.00%
	Avg	0.70%	0.15%	0.00%		Avg	0.20%	0.04%	0.00%
	Min	0.70%	0.10%	0.00%		Min	0.20%	0.06%	0.00%
16th	Max	0.10%	0.06%	0.00%	17th	Max	3.80%	1.47%	1.10%
	Avg	0.10%	0.03%	0.00%		Avg	3.30%	1.41%	1.00%
	Min	0.10%	0.07%	0.00%		Min	3.30%	1.28%	0.90%
17th	Max	1.80%	0.73%	0.60%	18th	Max	0.20%	0.05%	0.00%
	Avg	1.60%	0.76%	0.60%		Avg	0.20%	0.04%	0.00%
	Min	1.60%	0.68%	0.40%		Min	0.30%	0.06%	0.00%
18th	Max	0.10%	0.07%	0.00%	19th	Max	1.90%	0.87%	0.60%
	Avg	0.10%	0.03%	0.00%		Avg	2.90%	0.96%	0.40%
	Min	0.10%	0.07%	0.00%		Min	3.00%	1.06%	0.60%
19th	Max	1.00%	0.64%	0.40%	20th	Max	0.20%	0.06%	0.00%
	Avg	1.50%	0.73%	0.30%		Avg	0.20%	0.04%	0.00%
	Min	1.80%	0.79%	0.30%		Min	0.20%	0.06%	0.00%
20th	Max	0.10%	0.07%	0.00%	21st	Max	0.30%	0.08%	0.00%
	Avg	0.10%	0.03%	0.00%		Avg	0.70%	0.24%	0.00%
	Min	0.10%	0.07%	0.00%		Min	0.80%	0.12%	0.00%

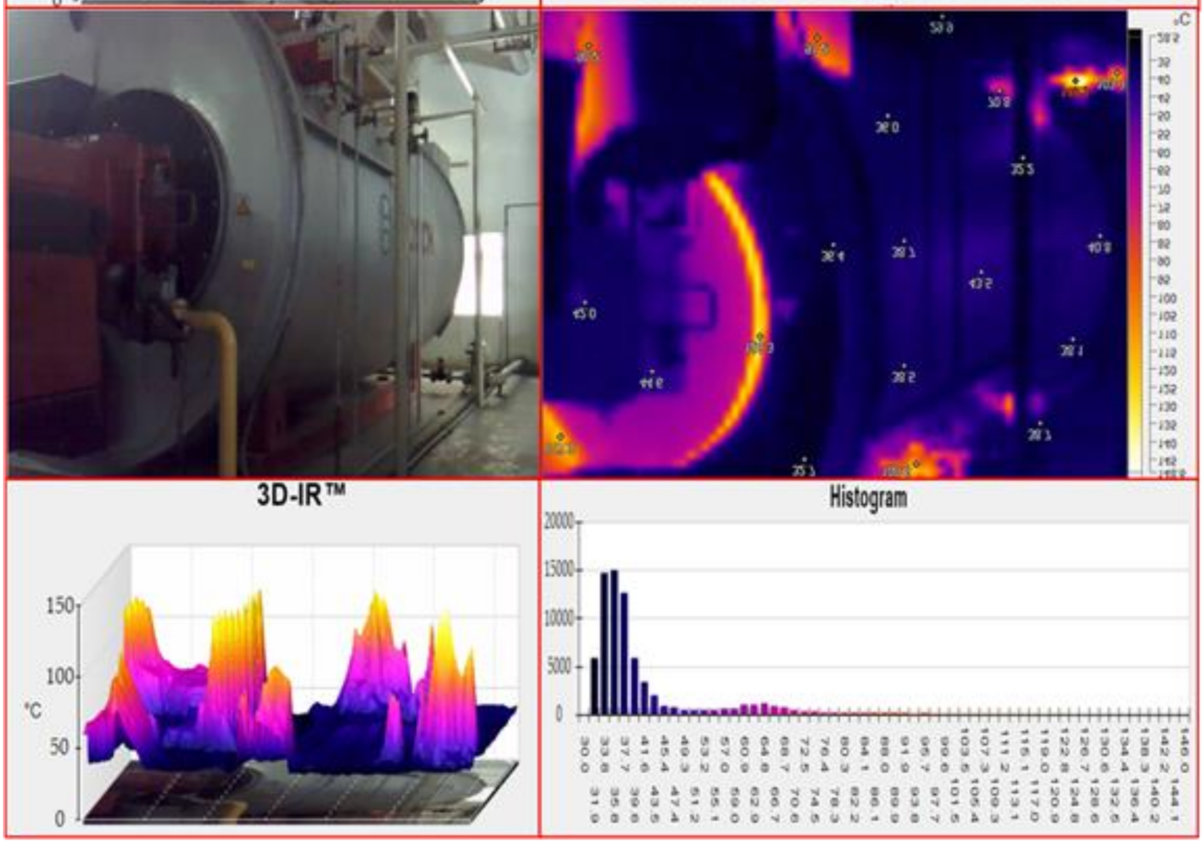
Appendix-2: Sample Thermal Assessment

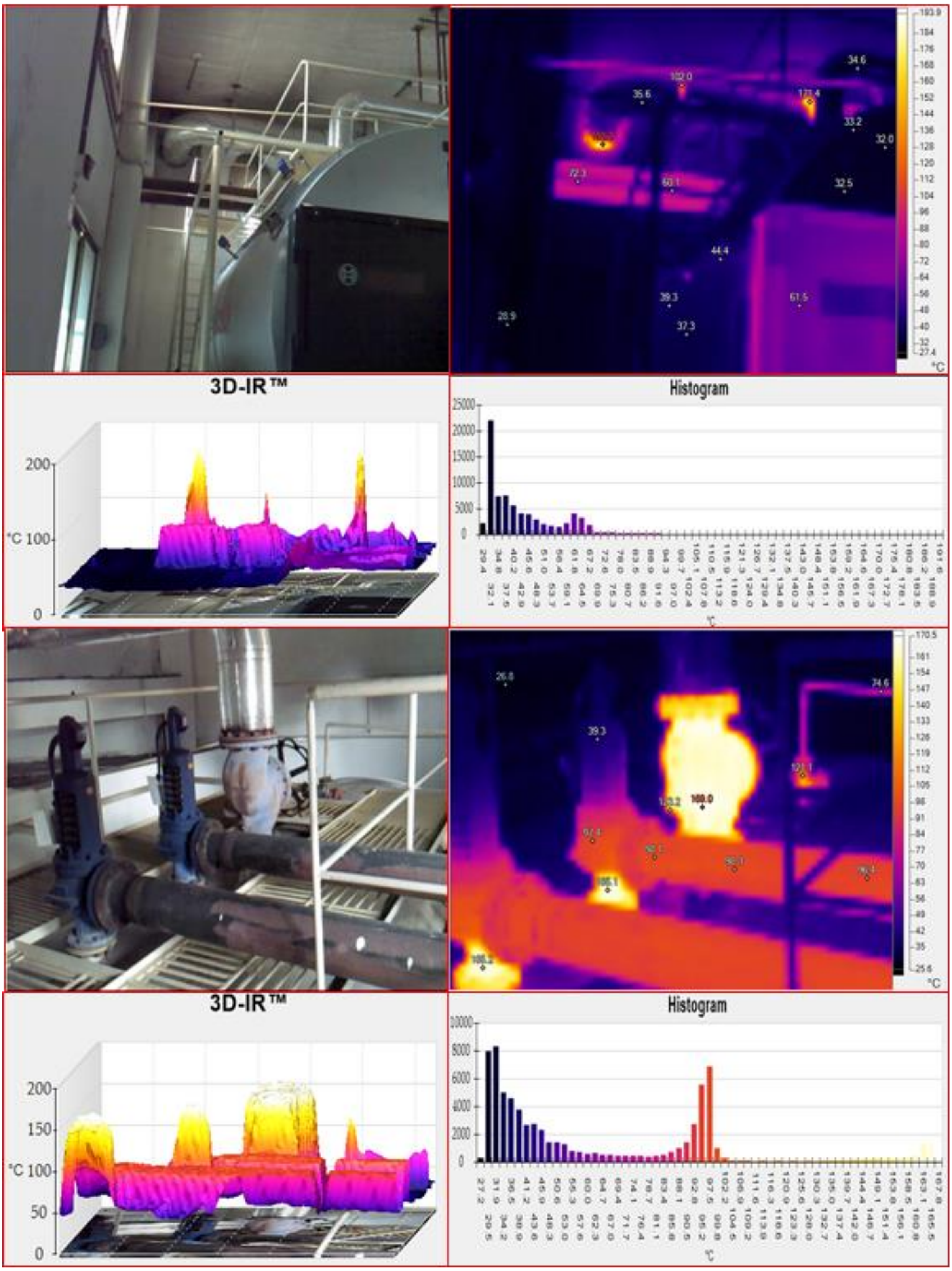


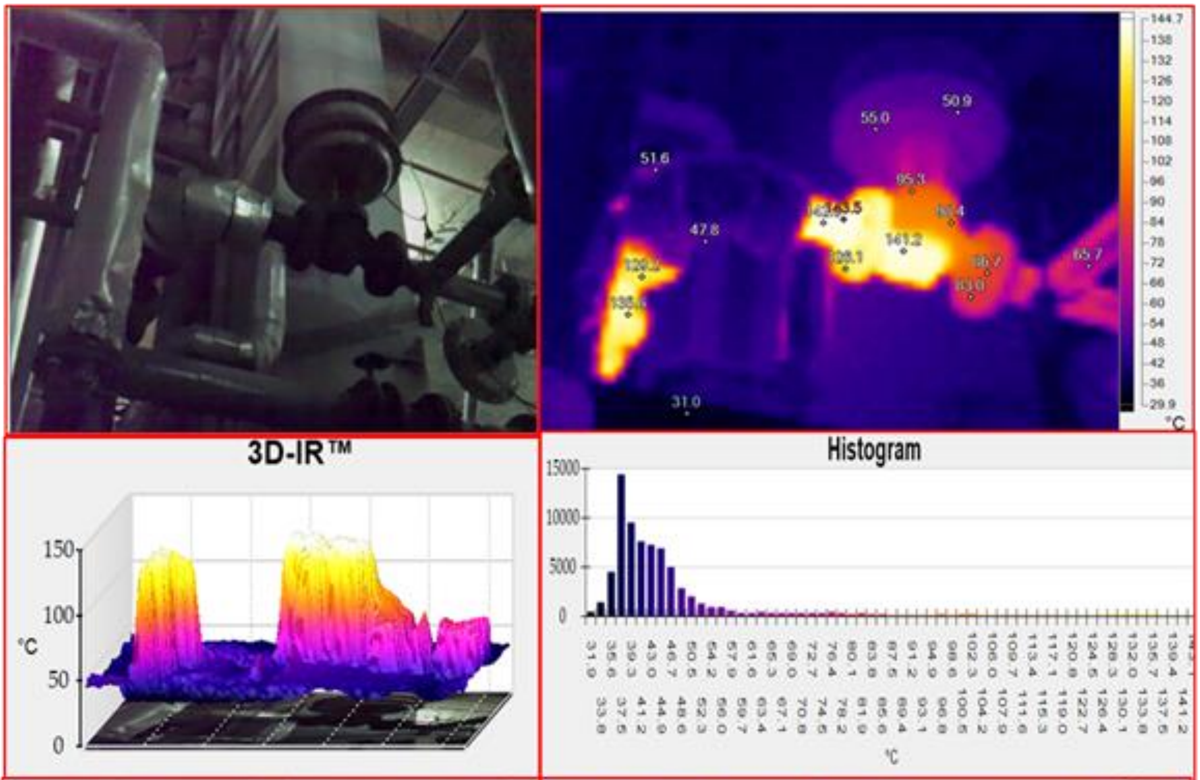

3D-IR ™
Histogram
°C

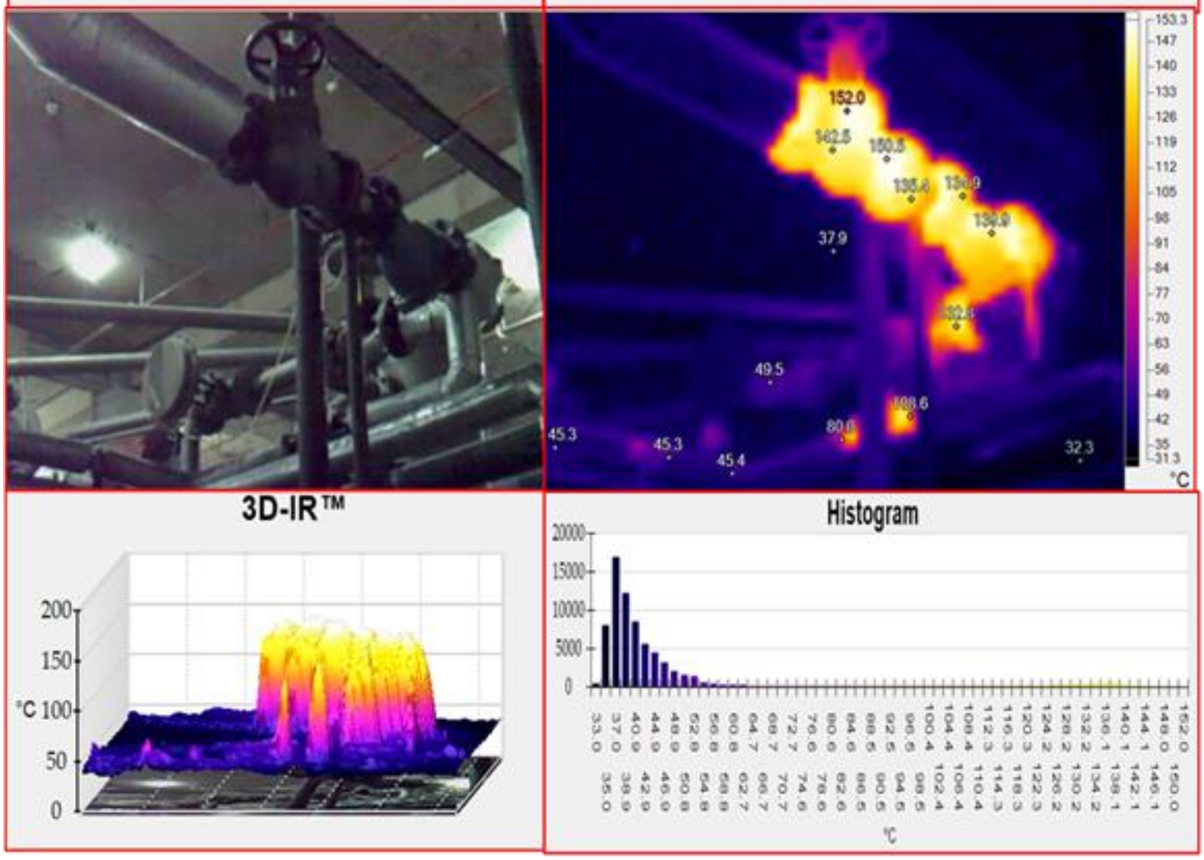

3D-IR ™
Histogram
°C

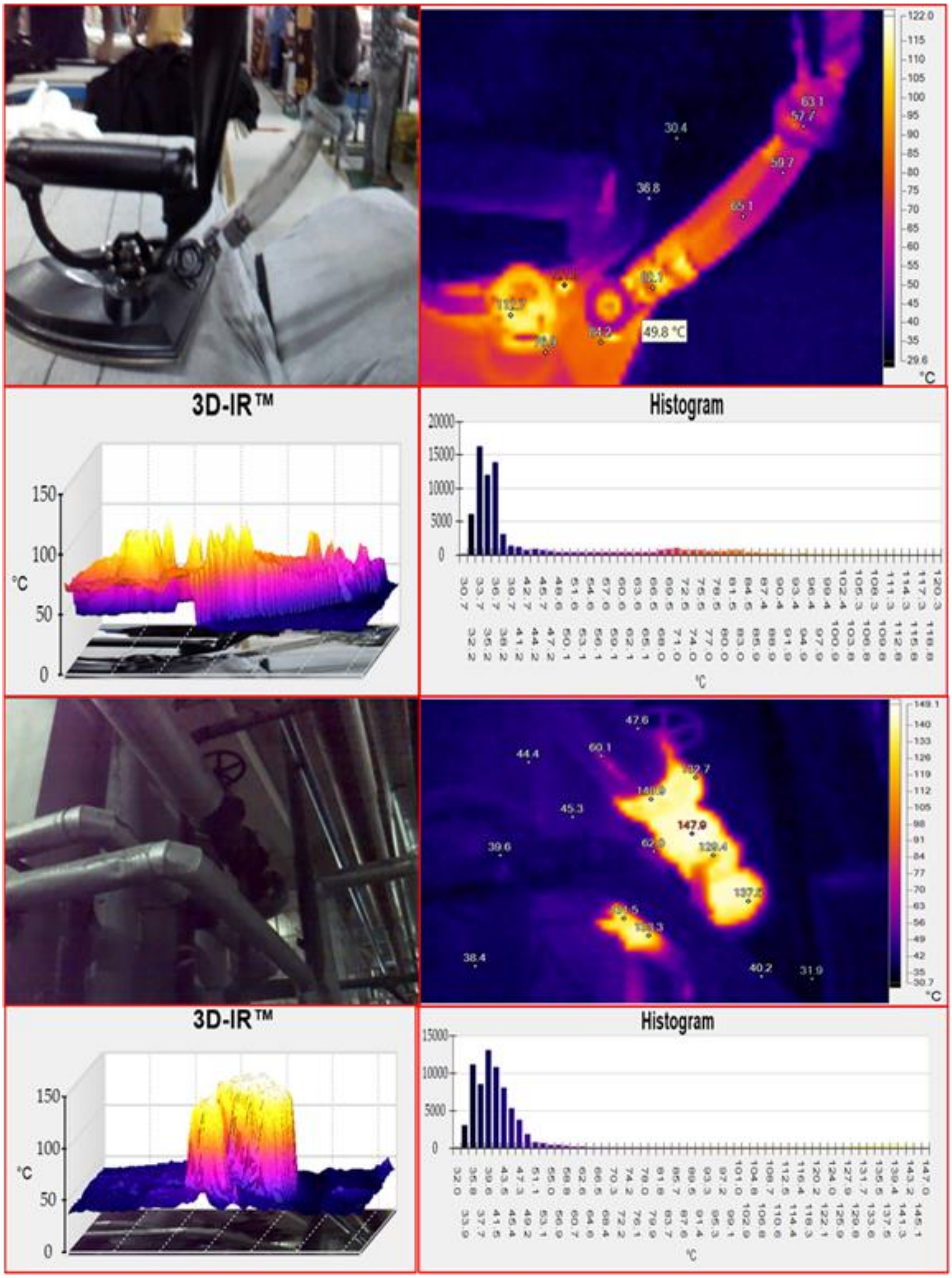

BOSCH
3D-IR™
Histogram


3D-IR™
Histogram


3D-IR™
Histogram
3D-IR™
Histogram


3D-IR™
Histogram
°C


3D-IR™
Histogram
°C


49.8 °C
3D-IR™
Histogram
°C
147.9
3D-IR™
Histogram
°C

APPENDIX-3: PHOTO DURING ASSESSMENT

Appendix-4: Energy Auditor certificate

SREDA
Sustainable and Renewable Energy Development Authority

গণপ্রজাতন্ত্রী বাংলাদেশ সরকার
টেকসই ও নবায়নযোগ্য জ্বালানি উন্নয়ন কর্তৃপক্ষ (স্রেডা)
বিদ্যুৎ বিভাগ
www.sreda.gov.bd

জ্বালানি নিরীক্ষক সনদ

নিবন্ধন নং	: জ্বা.নি(ইইই)-০৩০০০৩৪-০১৪	তারিখ	: ১৩ ডিসেম্বর, ২০২২ খ্রিঃ
পরীক্ষার রোল নং	: ২০২২১১০৩৪	সেশন	: ২০২২-২০২৩

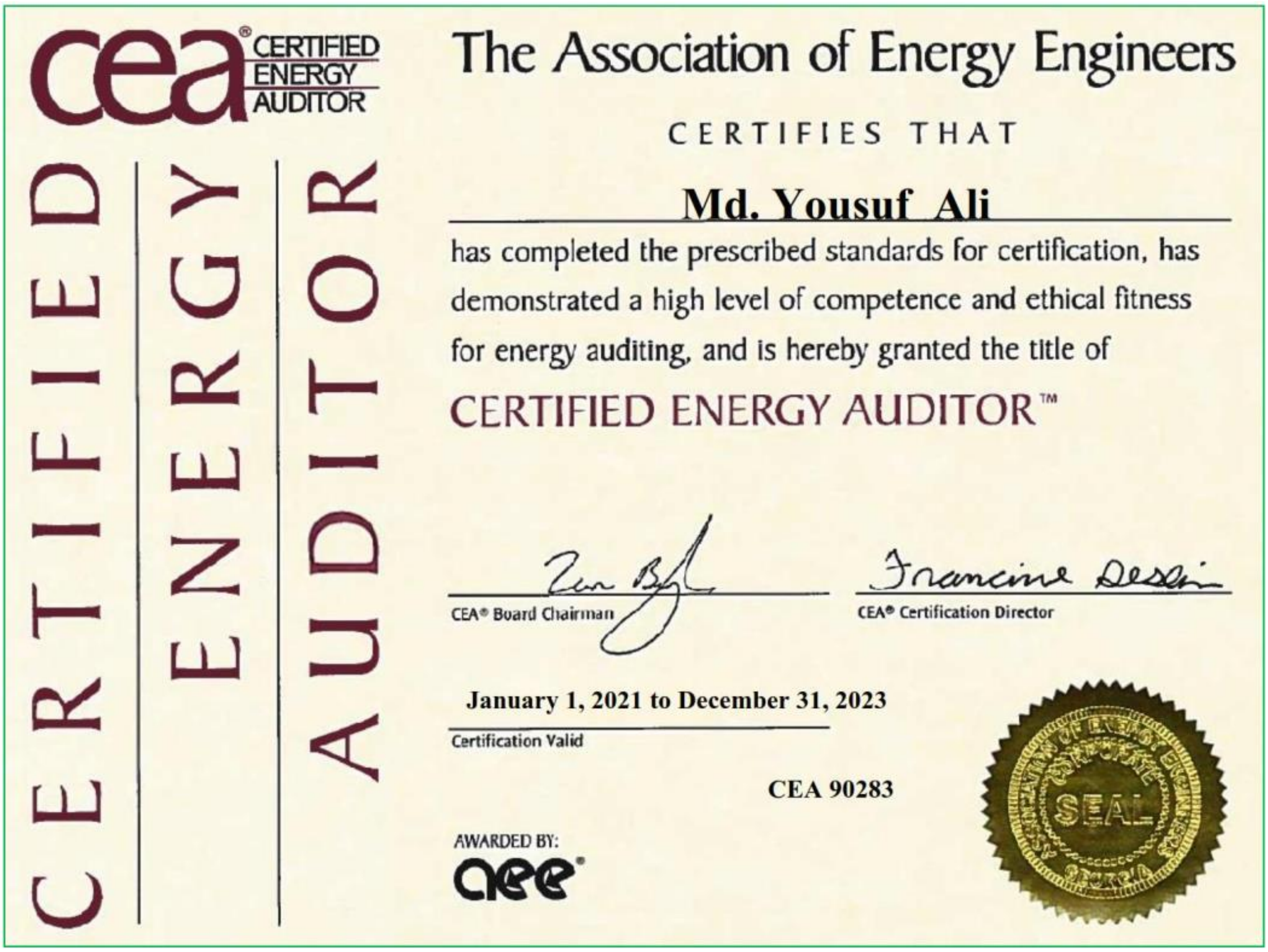
পরবর্তী নবায়নের তারিখ : ১৩ ডিসেম্বর, ২০২৭ খ্রিঃ

এই মর্মে প্রত্যয়ন করা যাইতেছে যে, জ্বালানি নিরীক্ষক সনদ পরীক্ষার সকল বিষয়ে উত্তীর্ণ হওয়ায় ***মোঃ ইউসুফ আলী***, পিতা: মোঃ এলাহী বকস্ মন্ডল, মাতা: মোছাঃ মরিয়ম নেছা কে জ্বালানি নিরীক্ষক সনদ প্রদান করা হইল।

২. ইহা প্রতি ৫ (পাঁচ) বছর অন্তর নবায়নযোগ্য হইবে।

স্বাক্ষর ও সীল

মুনীরা সুলতানা এনডিসি
চেয়ারম্যান (গ্রেড-১)
টেকসই ও নবায়নযোগ্য জ্বালানি
উন্নয়ন কর্তৃপক্ষ (স্রেডা)
বিদ্যুৎ বিভাগ



CERTIFIED ENERGY AUDITOR

cea® CERTIFIED ENERGY AUDITOR

The Association of Energy Engineers

CERTIFIES THAT

Md. Yousuf Ali

has completed the prescribed standards for certification, has demonstrated a high level of competence and ethical fitness for energy auditing, and is hereby granted the title of

CERTIFIED ENERGY AUDITOR™

CEA® Board Chairman

CEA® Certification Director

January 1, 2021 to December 31, 2023

Certification Valid

CEA 90283

AWARDED BY:

aee®

SEAL

THE END