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Improving Energy Efficiency by Effective Utilization of Biogas in Lime Kilns and Power Boiler

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Abstract: *The pulp and paper industry's transition towards renewable energy focuses on bio-mass streams and process derived bio-fuel. Among them, biogas generated from the bagasse wash water effluent contributes highly in energy security and reduced greenhouse emission. With continuous expansion of paper mills, biogas generation from the treated effluent increases, necessitating effective and reliable utilization methods to avoid flaring and energy loss. This paper highlights the systematic approaches adopted in Tamilnadu Newsprint and Papers Limited (TNPL) to improve energy efficiency through enhanced utilization of biogas in Lime kilns and Power boilers. Various system modifications were implemented at both generation and consumption ends, including commissioning of a lime kiln with biogas firing provision, reactor feed control based on gas pressure, gas holder instrumentation upgradation, real-time calorific value estimation, moisture removal systems and integration of biogas firing in power boilers during kiln shutdowns. In addition, methane detectors, flame arresters were installed for increased safety in the working environment. As a result, improved operational flexibility, reduced fossil fuel consumption and emission was achieved.*

Keywords: *Biogas, Lime Kiln, Reactor, Optimization, Energy security*

Introduction

Tamilnadu Newsprint and Papers Limited (TNPL) Unit-1 commissioned a biogas plant during 2002–03 to treat bagasse wash water effluent generated from pulp mill. Initially, the plant generated around 13,000–15,000 m³/day of biogas, which was utilized as a supplementary fuel in the lime kiln. Over time, TNPL increased its paper production capacity to 4,50,000 MT per annum. This resulted in higher effluent generation and an increase in biogas production of approximately 25,000 m³/day since 2021.

The increased biogas availability necessitated effective utilization strategies to manage high generation, volume variability, ensure system reliability and avoid flaring.

2. Biogas As A Renewable Bio Resource:

Biogas generated through anaerobic digestion of effluent is a renewable and environmentally friendly fuel. Its utilization in pulp and paper mills reduces dependence on fossil fuels, lowers greenhouse gas emissions and improves overall energy self-sufficiency. Efficient utilization of biogas requires appropriate system design, operational flexibility and higher quality.

The biogas generation has been increased substantially over time from 13,000 m³/day in the year 2003 to 25,000 m³/day (Figure 1). The generated biogas is used in Lime kilns and occasionally in Power boilers when the kilns are under shut.

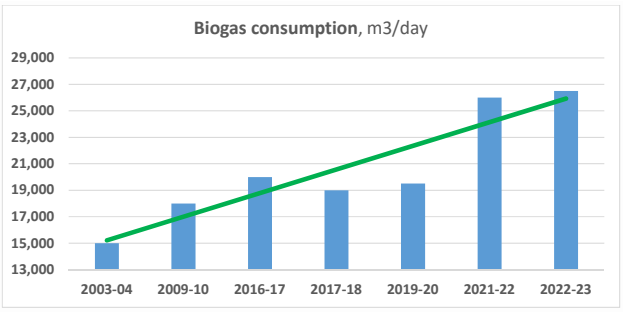

Figure 1: Biogas generation trend

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As a result, around 4,000 MT of furnace oil is saved and 0.02 million tons of CO2e emission is reduced annually. This is made possible by carrying out numerous enhancements and upgrades over time both at the generation and consumption end.

3. System Modifications And Optimization Measures:

To enhance the utilization of biogas and improve overall system efficiency, several modifications and optimization measures were implemented over different phases of plant operation. These measures focused on improving operational flexibility, reducing energy losses, ensuring safety, and maintaining consistent biogas quality.

3.1. Commissioning Of Second Lime Kiln Stream:

During mill development program, another lime kiln was commissioned in the year 2006 to increase production capacity and improve operational reliability. During the design and erection stage itself, provisions were made for firing biogas in the older kiln burner. This forward-looking integration eliminated the need for major retrofits at a later stage as done in the older kiln (Figure 2) and enabled effective utilization of biogas as a supplementary fuel, thereby reducing dependence on conventional fossil fuels.

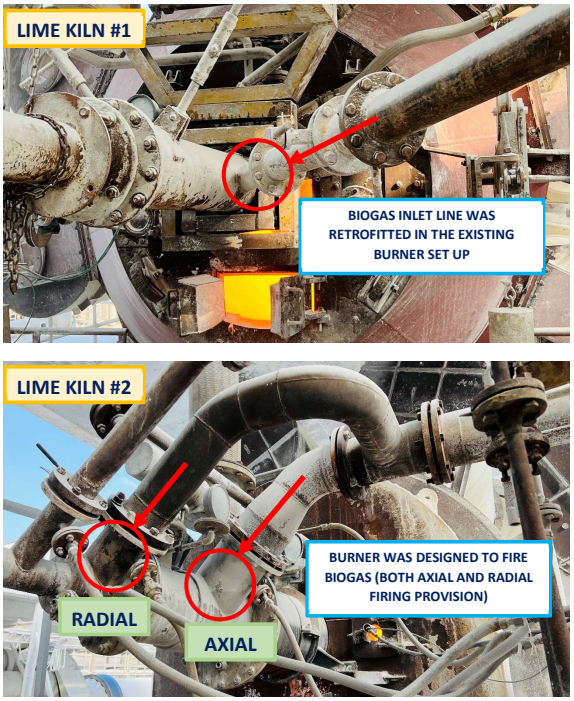

Figure 2: Comparison of biogas firing system in LIme kilns

3.2. Reactor Feed Control:

The generated biogas in the reactor is transferred to the gas holder. The generation of the biogas is not stable due to the bio-reaction based on COD. To optimise the reactor operation, a pressure transmitter has been introduced in the reactor outlet transfer line (Figure 3). Based on the pressure of the generated biogas, the feed to the reactor is controlled using a flow control valve.

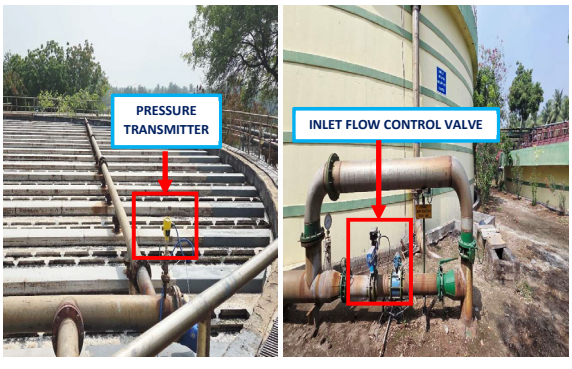

Figure 3: Control systems in biogas reactor

3.3. Upgradation Of Gas Holder Level Transmitter:

As a safety measure, level transmitter is installed in the gas holder and gas blower's speed is controlled with respect to the holder level. Earlier, ultrasonic type level transmitter was in service but the top of the holder is in conical shape leading to disturbances in level measurement. In order to overcome this, laser type level transmitter has been installed (Figure 4).

Figure 4: Control system in biogas holder

3.4. Optimisation At Consumption End:

Since, biogas is consumed in two lime kilns, there was a need to carry out a detailed study and incorporate a working principle for a safe and efficient operation. Following are the studies carried out:

3.4.1. Lime Kiln optimisation using Taguchi method:

Systematic trials with key inputs parameters like furnace oil pressure & temperature, biogas pressure, fuel mix ratio and feed sludge moisture with different settings were done using Design of Experiments (DOE)- orthogonal arrays (L16) to reduce the number of experiments. Signal-to-Noise (S/N) Ratio analysis was done to identify the parameter settings that yielded the best results and ANOVA was used to determine the percentage contribution of each parameters [1].

Also, control valves have been introduced in both the kilns but in one kiln it is operated based on flow and in other kiln, it is operated based on pressure. As a result, biogas flow is constant in one kiln and varies based on pressure set point in the other kiln

These tools helped in balancing fuel demand dynamically based on gas generation ensuring stable biogas supply while preventing pressure fluctuations that could impact plant safety and performance.

3.4.2. Real-time calorific value estimation:

In order to optimize the fuel mix ratio in lime kilns for efficient fuel consumption, biogas calorific value is estimated in real time using ultrasonic type mass flow meter for wet biogas without the requirement of gas chromatography (Figure 5). It is done by measuring the speed of sound and temperature of the gas providing the methane concentration with an accuracy of ± 1% from which the calorific value is arrived.

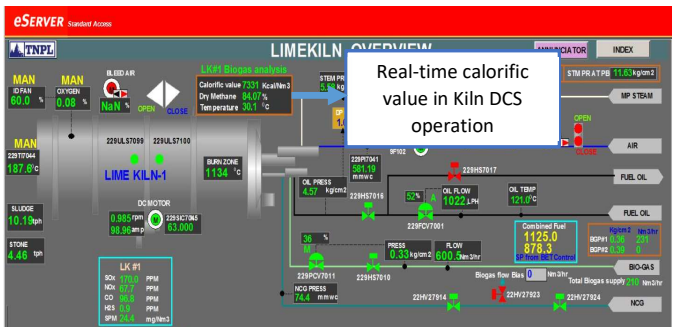

Figure 5: Real time calorific value assessment

3.4.3. Utilization of Biogas in Power Boiler:

Earlier, whenever the lime kilns were stopped due to maintenance or operational constraints, the generated biogas had to be flared, resulting in

energy loss and increased greenhouse gas emissions. To mitigate this issue, a system modification was carried out wherein the existing burner of coalfired power boiler was modified to operate in dual-fuel mode (Figure 6). This modification allowed the boiler to fire biogas thereby ensuring continuous utilization of generated biogas and significantly reducing flaring losses during lime kiln stoppage.

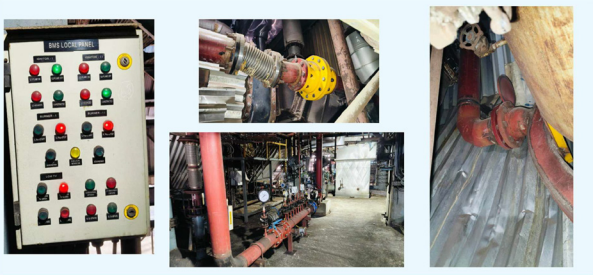

Figure 6: Burner modification in Power boiler

4. Improvement in Biogas Quality through Moisture Removal:

Moisture content in biogas adversely affects combustion efficiency and can cause corrosion in downstream equipment. Initially, only a manual drain system was available to remove condensed moisture from the gas lines. To improve biogas quality and ensure consistent combustion performance, automatic drain system has been introduced (Figure 7) in addition to the existing manual system and moisture removal trap.

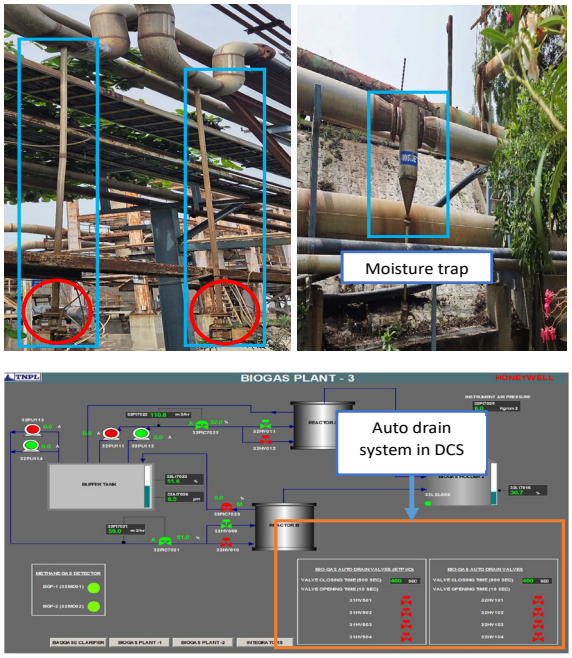

Figure 7: Auto drain valves in biogas transfer line

This ensured continuous and effective removal of moisture, leading to improved fuel quality, enhanced equipment life, and more stable kiln and boiler operations.

5. Safety Measures:

5.1. Methane Gas Detector:

Methane gas detectors have been installed near gas holders' blower outlet. It works by direct contact measurement (electro-chemical method) of the methane present in the atmosphere (Figure 8). This has helped to achieve the following:

- ❖ Fire hazard prevention- Efficient and prompt leak identification helps in preventing fires and explosions, especially in hazardous zones.
- ❖ Safe environment- By identifying leak, asphyxiation risk is avoided resulting in safe working environment.

5.2. Flame Arrester:

Flame arrester is an important safety device, installed to stop flashback, by allowing the gas/vapour to flow through but preventing the flame from

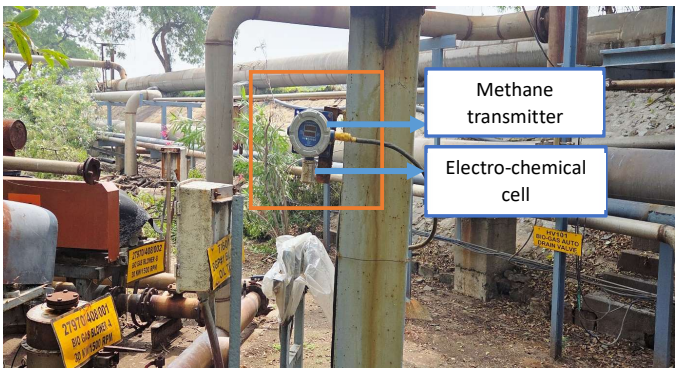

Figure 8: Methane detector

propagating back into the transfer line and further into a storage vessel by cooling the flame below its ignition point using a fine mesh.

In-Line flame arresters of deflagration types have been installed at both the lime kilns just before the point of consumption to prevent flashback (Figure 9).

5.3. Replacement of SS Pipelines with HDPE Lines:

Initially, biogas transportation was carried out through stainless steel (SS) pipelines. However, frequent leakages were observed due to corrosion and joint

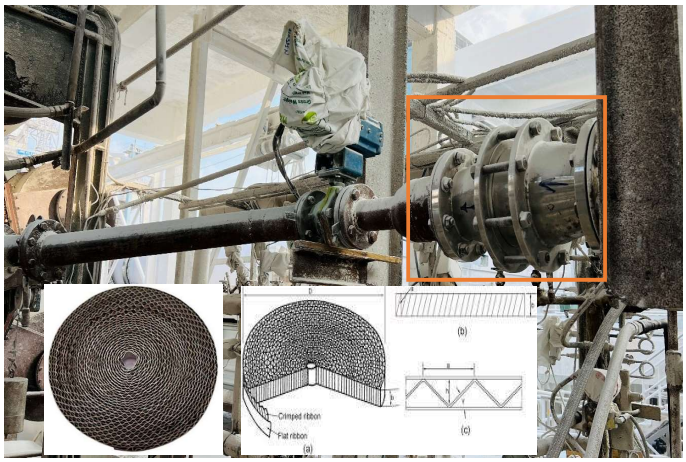

Figure 9: Flame arrestor in biogas inlet to kiln burner

failures, leading to safety concerns and repeated shutdowns for maintenance. To address this issue, SS pipelines were replaced with High Density Polyethylene (HDPE) pipelines. The use of HDPE significantly reduced leakage incidents due to its superior corrosion resistance and flexibility.

6. Conclusion:

Using biogas generated from effluent treatment plants in an effective manner can greatly improve overall energy efficiency and sustainability. By adopting a structured and phased approach involving system design improvements, advanced process control, real-time monitoring, and robust safety measures, the generated biogas can be used to its fullest potential. These initiatives not only resulted in huge savings in terms of fossil fuel consumption and reduction in greenhouse gas emissions but also enhanced energy self-sufficiency.

Acknowledgment:

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