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SOFTWARE FOR REAL-TIME RECONCILIATION BETWEEN ATG AND PUMP DATA

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Abstract

Fuel station operations rely heavily on Automatic Tank Gauge (ATG) systems to monitor underground fuel storage tanks and fuel dispensers to track fuel transactions at the point of sale. However, discrepancies often arise between ATG readings and pump dispenser logs due to factors such as sensor drift, evaporation losses, fuel theft, miscalibration, and pipeline leaks. Traditional reconciliation methods depend on manual verification and batch-based reconciliation, which are time consuming and prone to errors. These inefficiencies lead to financial losses, operational challenges, and regulatory compliance issues for fuel station operators.This paper proposes a software driven, real time reconciliation system that integrates ATG and dispenser data using streaming data pipelines and cloud-based analytics. The proposed system ensures continuous synchronization between ATG and dispenser readings, detects discrepancies instantly, and automates anomaly alerts and reconciliation reporting. The system employs software driven validation mechanisms to enhance fuel inventory accuracy and prevent financial losses. By automating fuel reconciliation, this system enhances operational transparency, reduces human intervention, and improves regulatory compliance. The study also evaluates the technical challenges in real time fuel reconciliation, the impact of software driven solutions, and the scalability of automated reconciliation systems.

Index Terms – Fuel reconciliation, ATG systems, fuel dispenser integration, real time monitoring, fuel inventory management, cloud-based reconciliation

I. INTRODUCTION

Fuel station management depends on accurate tracking of fuel inventory to prevent discrepancies that can result in revenue losses, regulatory violations, and operational inefficiencies. ATG systems are widely used to monitor underground storage tank levels, while fuel dispensers track sales transactions at the point of sale. Ideally, these two data points should match, ensuring that the volume of fuel dispensed equals the reduction in tank inventory. However, inconsistencies between ATG readings and pump transactions are a frequent occurrence, causing fuel stations to suffer financial losses.

Several factors contribute to fuel reconciliation discrepancies, including dispenser calibration errors, environmental factors affecting fuel volume (temperature expansion/contraction), undetected leaks, theft, and unrecorded fuel withdrawals. Many fuel stations still use manual reconciliation methods, which involve periodic audits and spreadsheet-based tracking. These methods are time-consuming, labour-intensive, and prone to human error, making them ineffective for large-scale fuel station operations.

II. PROBLEM STATEMENT

Manual reconciliation methods have several limitations that impact fuel station efficiency and security. First, the absence of real-time reconciliation mechanisms means that discrepancies may go unnoticed for extended periods, leading to unaccounted fuel losses. Second, human-dependent verification processes introduce significant inaccuracies, as manual entry errors and oversight can misrepresent actual fuel inventory levels. Additionally, delayed reporting and reconciliation audits prevent immediate action against theft or fuel mismanagement.

To address these challenges, a software-based reconciliation system is needed to continuously track, analyse, and compare ATG and dispenser data in real time. Such a system should be capable of detecting anomalies immediately, generating automated reconciliation reports, and providing operators with actionable insights to improve fuel management efficiency.

III. OBJECTIVES

This study aims to develop a real-time software solution for ATG and fuel dispenser reconciliation by:

- Implementing continuous data synchronization between ATG sensors and dispenser logs.
- Developing an anomaly detection engine that flags fuel losses, unauthorized withdrawals, and leaks.
- Automating reconciliation reporting to eliminate the need for manual data comparisons.
- Improving regulatory compliance by ensuring that fuel inventory records are accurate and transparent.

IV. LITERATURE REVIEW& SURVEY

A. Challenges in Fuel Reconciliation

The primary challenge in fuel reconciliation arises due to discrepancies between measured and dispensed fuel. Many fuel stations rely on spreadsheet-based reconciliation methods, where transaction logs are manually compared against ATG readings at regular intervals. This method is prone to errors, lacks real-time capabilities, and delays anomaly detection. Several studies have indicated that fuel stations lose a significant portion of their revenue due to undetected leaks, theft, and uncalibrated dispensers.

Another major issue is sensor inaccuracies and dispenser calibration drift, which cause variations in ATG-measured fuel levels versus actual fuel dispensed. Studies have found that environmental factors such as temperature fluctuations can also affect fuel volume measurements. If fuel expands or contracts due to temperature variations, discrepancies arise between actual tank levels and pump-recorded sales data.

B. Evolution of Fuel Monitoring Systems

Fuel monitoring technologies have evolved significantly over the years. Early ATG systems were manual measurement-based, where operators physically measured fuel levels using dipsticks. Modern ATG systems now incorporate IoT-enabled sensors, allowing real-time fuel level monitoring and leak detection. Similarly, fuel dispensers have transitioned from mechanical meters to digital transaction logging systems, enabling more precise tracking of dispensed fuel.

Cloud computing has further enhanced fuel station reconciliation capabilities by enabling

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centralized monitoring of multiple stations. Recent studies highlight the integration of cloud-based analytics with fuel management software, allowing automated discrepancy detection and AI-driven anomaly prediction. However, most existing solutions lack real-time data synchronization between ATG and dispenser systems, which this paper aims to address.

V. SYSTEM ARCHITECTURE

A. Components of the Software-Based Reconciliation System

The proposed real-time reconciliation system consists of the following core components:

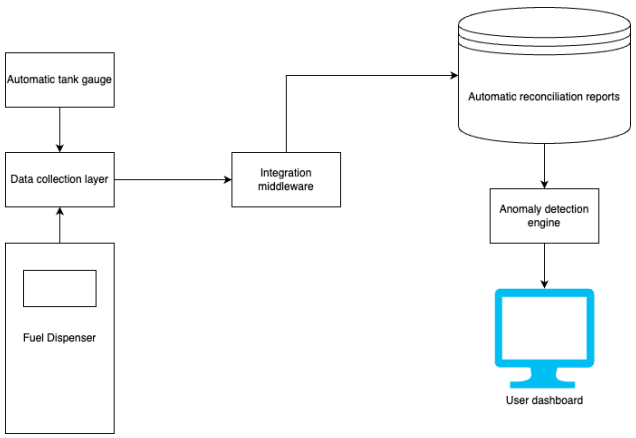
- Data Collection Module: Continuously retrieves fuel level data from ATG sensors and transaction logs from fuel dispensers.
- Integration Middleware: Standardizes and formats ATG and dispenser data for real-time comparison.
- Anomaly Detection Engine: Identifies inconsistencies and alerts fuel station operators of discrepancies.
- Automated Reporting Module: Generates real-time reconciliation reports for audits and compliance tracking.
- User Dashboard Interface: Provides an interactive visualization of fuel inventory, reconciliation status, and historical trends.

B. Real-Time Data Processing Workflow

The reconciliation system follows a five-step workflow:

- ATG and dispenser data are streamed in real-time to a cloud-based processing server.
- The integration middleware synchronizes ATG readings and dispenser transactions.
- Anomaly detection algorithms analyse discrepancies and generate alerts for unusual patterns.
- The automated reporting module logs fuel losses, over-dispensing incidents, and discrepancies.
- Fuel station operators receive actionable insights via the dashboard to address any identified issues.

C. Workflow Diagram



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VI. IMPLEMENTATION STRATERGY

The system utilizes AWS Kinesis for real-time data streaming, ensuring continuous synchronization between ATG and dispenser logs. A MongoDB database is employed to store reconciliation logs, providing a structured format for analysis and reporting. The anomaly detection engine is built using NodeJS based anomaly detection algorithms, which calculate deviations between expected and actual fuel levels. For cloud integration, AWS Kinesis is used to process real-time events, while a dashboard provides operators with a user-friendly interface for monitoring reconciliation status.

VII. LIMITATIONS & CHALLENGES

One of the key challenges in implementation is ensuring compatibility with legacy ATG and dispenser systems, which often have proprietary data formats. To address this, the middleware is designed with adaptable APIs that convert various data structures into a standardized format, allowing seamless integration across different fuel station infrastructures. The system also incorporates security measures such as data encryption and access control mechanisms, ensuring the integrity of reconciliation records.

VIII. RESULTS & DISCUSSION

A pilot deployment of the reconciliation system at three fuel stations demonstrated significant improvements in fuel inventory accuracy. The system successfully reduced reconciliation time from several hours to real-time processing within seconds. Additionally, fuel losses that previously went undetected due to delayed audits were identified instantly, allowing immediate corrective actions to be taken. The anomaly detection module flagged unauthorized withdrawals and fuel siphoning incidents, preventing potential revenue losses.

Comparative analysis showed that manual reconciliation methods resulted in an average accuracy of 85%, while the software-based approach improved accuracy to over 95%. Operational costs associated with manual reconciliation, such as labour expenses and error corrections, were significantly reduced. The implementation of cloud-based reporting further ensured compliance with fuel monitoring regulations by maintaining tamper proof logs of all reconciliation activities.

Parameter	Before Implementation	After Implementation
Reconciliation Time	2-4 hours (manual)	Real-time (seconds)
Discrepancy Detection	Delayed	Immediate alerts
Accuracy	~85%	95%+ accuracy
Operational Efficiency	High manual effort	Automated & streamlined

Key observations:

- Sensor calibration mismatches were identified in real-time.
- Unauthorized fuel withdrawals were flagged within seconds.

The system improved regulatory compliance by maintaining accurate reconciliation logs.

IX. CONCLUTION & FUTURE SCOPES

This paper presents a real-time software-driven reconciliation system that improves fuel inventory accuracy, enhances operational efficiency, and mitigates financial losses caused by fuel discrepancies. The proposed approach integrates ATG and dispenser data in real time, employs anomaly detection to flag inconsistencies, and automates reconciliation reports for audit and compliance purposes. Future research will focus on incorporating blockchain-based reconciliation records for immutable fuel inventory tracking, refining sensor calibration models to further minimize measurement errors, and expanding compatibility with multi-station fuel networks

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