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Industrial Boiler Automation Using Programmable Logic Controllers And Artificial Intelligence

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Abstract
This paper outlines the various stages of operation involved in the conversion of a manually operated boiler towards a fully automated boiler. Artificial Intelligence (AI) techniques are becoming useful as alternate approaches to conventional techniques. They have been used to solve complicated practical problems and now a day is very popular. They can learn from examples, fault tolerant in the sense they are able to handle noisy and incomplete data and once trained can perform faster prediction and generalization. AI based systems are used mainly because of their symbolic reasoning, flexibility and explanation capabilities. This paper briefly presents the main AI techniques and outlines an application in boiler control. Over the years the demand for high quality, greater efficiency and automated machines has increased in this globalized world. The initial phase of the paper focuses on passing the inputs to the boiler at a required temperature, so as to constantly maintain a particular temperature in the boiler. The Air preheater and Economizer helps in this process. And the paper mainly focuses on level, pressure and flow control at the various stages of the boiler plant.
Thus the temperature in the boiler is constantly monitored and brought to a constant temperature as required by the power plant. The automation is further enhanced by constant monitoring using SCADA screen which is connected to the PLC by means of communication cable. By means of tag values set to various variable in SCADA the entire process is controlled as required. At the automated power plant, the boiler is controlled by Variable Frequency Drive (VFD) to put in action the required processes to be carried out at the boiler. Thus, the entire cycle is carried out as a paper and at various stages each phase is detailed out. This paper has proved to be very efficient practically as the need for automation grows day by day. This project outlines the design and development of boiler automation system using PLC and sensors. This paper outlines the various stages of operation involved in the conversion of manually operated boiler towards a fully automated boiler. Over the years the demand for high quality, greater efficiency and automated machines has increased in this globalized world. The initial phase of the paper focuses on passing the inputs to the boiler at a required temperature, so as to constantly maintain a particular temperature in the boiler. The paper gives basic approach to move towards automation at higher level and totally digitize the industry so we can obtain efficient output in less time.

Keywords: Automation, PLC – SCADA, Boiler, Machine learning.

INTRODUCTION
Over the years the demand for high quality, greater efficiency and automated machines has increased in the industrial sector of power plants. Power plants require continuous monitoring and inspection at frequent intervals. There are possibilities of errors at measuring and various stages involved with human workers and also the lack of few features of microcontrollers. Thus this paper takes a sincere attempt to explain the advantages the companies will face by implementing automation into them. The boiler control which is the most important part of any power plant, and its automation is the precise effort of this paper.

In order to automate a power plant and minimize human intervention, there is a need to develop a SCADA (Supervisory Control and Data Acquisition) system that monitors the plant and helps reduce the errors caused by humans. PLCs (Programmable Logic Controllers) are used to store instructions for implementing functions like logic, sequencing, timing, counting, and arithmetic and to control various machine processes through digital or analog input/output modules. SCADA is used to monitor the system. In sectors like energy, transportation, oil and gas refining, water and waste management, and telecommunications, systems are used to monitor and manage a plant or piece of equipment.

REVIEW METHODOLOGY.

There are many different types of boilers, they are as follows
1. Fire-tube boiler
2. Water-tube boiler
3. Superheated steam boiler

A. FIRE-TUBE BOILER.

Fig1. Firetube boiler

The boiler shell of a fire tube boiler is filled with water, and the tubes are arranged horizontally. The water tank has a volume within to hold the steam and is only partially filled with water. Flues are long, horizontal tubes that heat water by transporting hot combustion gases across the water tank. The hot gases' journey is extended by the furnace, which is located at one end of the fire tube. The steam pressure in fire tube boilers is roughly 360 psig.
B. Water-tube boiler These vertical pipes, known as risers, run from the water drum at the bottom of the boiler to the steam heaters at the top of the boilers. In water tube boilers, tubes are placed vertically in the firebox, and water flows through these tubes, becoming heated as it passes through them. Because the high-pressure steam and water are kept in smaller diameter pipes that can sustain the high pressure, water tube boilers are recommended for high-pressure applications.
C.Boiler with superheated steam Reheating steam that has been generated in the boiler results in superheated steam, which differs from the original steam, known as saturated steam, in that it contains water vapor and condenses more slowly than saturated steam. In the super heater section, the steam's

temperature rises to about 370 degrees Celsius, but its pressure stays constant. Since superheated steam eliminates all droplets, it is mostly utilized to move turbines.

PROGRMMABLE LOGIC CONTROLLERS IN BOILER SYSTEMS.

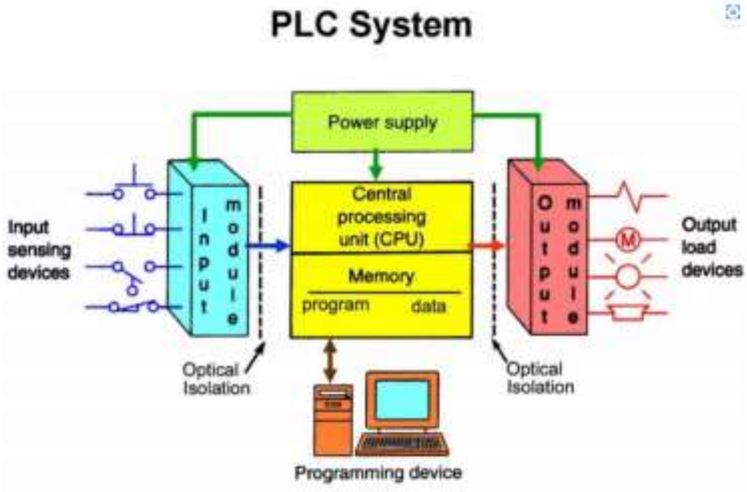

Fig 2. PLC System.

PLCs are powerful industrial computers made to handle control tasks. PLCs are mainly utilized in boiler systems for:

- Monitoring parameters: pressure, temperature, fuel flow, water levels. • Controlling actuators: valves, pumps, burners.
- Executing safety interlocks: emergency shutdowns, alarms.
- Implementing sequences: boiler startup and shutdown procedures.

PLCs offer real-time control, modularity, and high reliability, making them ideal for industrial environments. The Central Processing Unit (CPU), Memory, Input Modules, Output Modules, and Power Supply make up a programmable logic controller. The figure displays the hardware block diagram for the APLC. The programming terminal in the diagram is not a part of the PLC, but it is essential to have a terminal for programming or monitoring a PLC. In the diagram, the arrows between blocks indicate the information and power-flowingdirection.

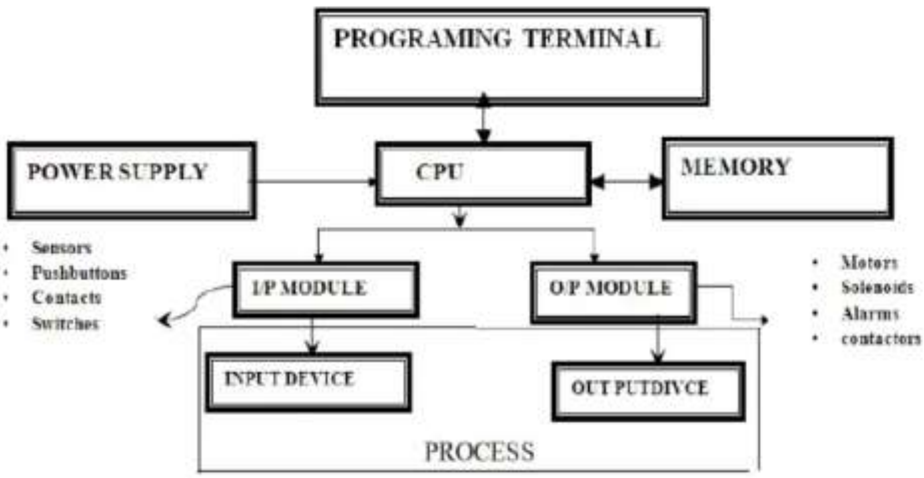

Fig 3. Role of artificial intelligence in boiler automation.

AI introduces a new level of intelligence and adaptability into boiler control systems. Its main contributions include:
Predictive Maintenance: Proactive maintenance is made possible by AI models that have been trained on previous sensor data to anticipate breakdowns before they happen.
Process Optimization: Algorithms that use machine learning can dynamically modify control parameters to maximize heat production and fuel usage.
Anomaly Detection: By spotting odd trends in sensor data, AI systems can find errors or inefficiencies early.
Energy Efficiency: By optimizing combustion parameters, AI can lower pollutants and fuel consumption.

SYSTEM ARCHITECTURE.

A typical AI-PLC integrated boiler automation system includes:
1. Sensors and Actuators: Gather data in real time and manage physical operations.
2. PLC Layer: Performs low-level control, signal processing, and safety logic.
3. AI Layer:
4. Trained models (e.g., neural networks, support vector machines).
5. Data analytics and decision-making capabilities.
6. Interfaces with the PLC via industrial protocols (Modbus, OPC UA).
7. Human-Machine Interface (HMI): Displays status and analytics, allows operator input.
8. Data Storage and Cloud Integration: For long-term data analysis and remote monitoring.

IMPLEMENTATION CONSIDERATIONS.

Implementing AI and PLC integration in industrial boiler systems requires careful planning
Data Quality: AI systems need clean, labeled historical data for accurate model training.
Real-time Constraints: AI decisions must meet real-time requirements; edge AI deployment may be necessary.
Cybersecurity: Secure communication between AI and PLC is essential to protect against cyber threats.
Regulatory Compliance: Must adhere to industrial safety and emissions standards. Scalability: System should accommodate changes in demand or configuration.

BOILER AUTOMATION.

To automate a power plant and reduce human error, a PLC and SCADA system that minimizes human error must be developed. The PLC and SCADA interface via communication cables, and the SCADA uses various sensors to monitor the boiler's temperature, pressure, and water level, and the PLC receives the corresponding output. The figure depicts the block diagram of boiler automation, which consists of PLC, SCADA, and sensors to monitor and control the boiler's entire operation.
Here, the temperature is measured using a Resistive Temperature Detector Pt 100 (RTD PT 100), the boiler's internal pressure is measured using an RT pressure switch, and the boiler's feed water level is detected using float switches. They measure its temperature. The flow rate is kept at 130% in one pump and 75% in another. Thus, the breakdown of any one pipe does not influence the boiler operation. A PLC is used to turn on the heater. Sensors monitor the corresponding pressure and temperature.
A significant factor in the production of steam is water. The push button is turned on first, followed by the PLC, SCADA, and several sensors. A feed water pump switch is used to turn the feed water pump on. In order to recover the heat in the outgoing gasses by transferring it to the water, the water from the water tank is let to go through two parallel pipes to the boiler and then through an economizer. The heated water is then forced through a water drum and steam. Water should be kept at least 50% in this. Float switches are used to detect the water level.
Float switches detect changes in the level and communicate the proper control signal to the PLC when the level is less than or more than 50%. Therefore, by properly tuning the PID controller, the water level may

be maintained at 50% regardless of changes in the disturbance variable. Over 75% of the water in the water drum is kept there. The motor will turn on when the water level drops below 2000 liters. The entire system will be in off state if the boiler's internal temperature and pressure rise above acceptable levels. To prevent catastrophic failure, the corresponding automated check valves are opened.

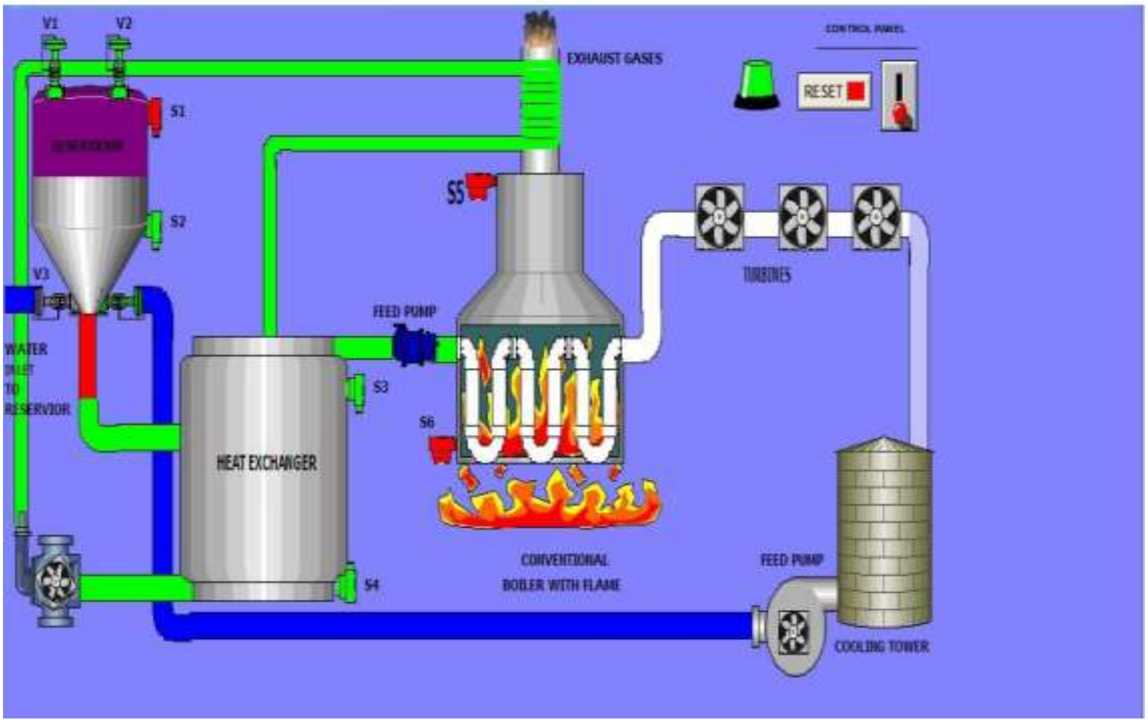

Fig 4. Boiler Control System.

B. Control parameters:
1. Temperature Control:
• Steams drum temperature, underbed boiler temperature, Force draft temperature, Flue gas temperature, Induced draft temperature, feed water temperature.
2. Pressure Control: -
• Force draft pressure, Induced draft pressure, Steam drum pressure, Turbine inlet steam pressure, and flue gas pressure.
3. Level Control Steam Drum level,
4. Water level.

B. Control parameters:
C. Temperature control options include:
feed water temperature, force draft temperature, flue gas temperature, induced draft temperature, steam drum temperature, and underbed boiler temperature. Pressure control options include flue gas pressure, steam drum pressure, turbine inlet steam pressure, forced draft pressure, and induced draft pressure. C. Boiler: In essence, a boiler is a closed vessel that heats water until it turns into steam at the necessary pressure. Boilers come in two primary varieties: fire tube boilers and water tube boilers. Initially, a furnace burns fuel, usually coal, producing hot gases. When these heated gases come into contact with a water vessel, their heat is transferred to the water, which causes the boiler to produce steam. After that, the steam is pumped to the thermal power plant's turbine. Boilers come in a wide variety and are used for a variety of tasks, such as heating the surrounding air, sterilizing equipment, disinfecting a particular region, and operating a production unit.

D. Temperature sensor:
To detect temperature changes, a Resistance Temperature Detector (RTD PT 100) is utilized. This passive circuit element exhibits a predictable increase in resistance as the temperature rises. A precision platinum resistor with a 100-ohm reading at 00 c is called a PT-100. It is necessary to convert the resistance to a voltage and utilize that value to drive a differential input amplifier in order to measure the resistance. The differential input amplifier will reject the common mode noise on the leads of the RTD and provide the greatest voltage sensitivity. Either connecting the RTD element in one leg of a Wheatstone bridge activated by a continuous reference voltage or connecting it in series with a precision current reference and measuring the accompanying IR voltage drop are the two common methods for measuring the RTD signal.
E. Pressure Sensor.
The boiler's internal pressure is sensed via an RT pressure switch. A seamless bellows is used as a sensing element in RT Series pressure switches. To accommodate different types of process media, the bellows might be made of stainless steel or phosphor bronze. The mechanism is housed in an IP66 (weatherproof) casing made of die-cast aluminum (DMC). The range of pressure is -1 to 30 bar.
F. Float switches.
One tool for determining the liquid level in a tank is a float switch. A pump, indicator, alarm, and otherzdevices may use the switch. Float switches come in a variety of sizes and can be as basic as a mercury switch within a hinged float or as sophisticated as a number of optical or conductance sensors that provide distinct outputs when the liquid in the tank reaches a variety of levels. The temperature, pressure, and water level are measured in this article using a variety of sensors. PLC is used to control the operation, and SCADA is used to monitor the parameters. The entire system will shut down and automatic check valves will open to discharge the steam and pressure if the temperature and pressure beyond a predetermined threshold.
To prevent catastrophic failure in the event of an emergency, automated check valves are opened and the alarm is activated. WPL Soft is used to model the ladder diagram of the Delta PLC, and InTouch Wonderware software is used to simulate the SCADA architecture of the boiler automation. Future studies will concentrate on the application-oriented deployment of SCADA internet connection for remote boiler automation monitoring.

RELATED WORKS.
To monitor operations, the boiler industry's BMS (Boiler Monitoring and Control System) employs a range of techniques and technologies. utilizing sensors and IOT, Navneet Kumar Verma (Verma et al. 2018) automated and simulated a boiler system. Data was gathered from the thermal power plant utilizing data mining, pattern recognition, and modeling techniques. In order to detect any departure or malfunction in boiler feed pumps from regular operations, Marek Moleda developed a model that makes use of IoT, big data, and cloud computing (Moleda et al. 2020). While a machine tool was operating, Stefano Tedesch put in place a data acquisition unit that could learn on its own. The methodical approach concentrated on hazards that result in data or information loss for the monitoring system. In later evolution, this monitoring system served as a remote-control system for a variety of actuators. This analyzed the critical problems with a focus on the manufacturing environment and set the groundwork for the development of a secure remote monitoring system for machine tools using IoT devices (Tedeschi et al. 2017).
Tawanda Mushiri controlled and maintained the boiler's parameters using fuzzy logic and CBM. This decreased the production of clinker and improved boiler efficiency (Mushiri et al. 2018). Y. Nandini Reddy suggested a technique that uses wireless connection to remotely monitor and regulate boiler temperature. The Internet of Things (IoT) serves as the communication platform for this approach (Reddy et al. 2017). F.M. Aiysha Farzana proposed an autonomous boiler monitoring system based on smart devices to maintain pressure, temperature, steam, and flow level. The monitoring system used GSM to send alert messages to the public whenever any aberrant values of temperature, steam, flow level, or pressure were

picked up by relevant sensors (Farzana et al. 2019). An automated system for continuous monitoring was introduced by K. Gowri Shankar. It connected to the PLC via a communication wire and SCADA. Shankar (2008) L. A paper on using wireless communications to remotely monitor and control boiler settings was presented by Navaneeth. In 2016, Navaneeth and Rukkumani. A system that used CAN for information sharing and LabView for process control was put into place by Joshuva Arockia Dhanraj (Dhanraj and Ramanathan, 2020). Think Speak and the Internet of Things were used by S. Mythili to develop a method for monitoring boiler parameters (Mythili and Gokulkumar, 2018). The boiler industry was monitored by Aixia Duan, who developed a ZigBee-based online gas leak monitoring system (Duan et al. 2018).

LITERATURE REVIEW.

2.1 Historical Perspective on Boiler Automation.

Industrial boiler automation has progressed from basic mechanical systems to intricate computercontrolled systems. Early systems had no instrumentation to monitor temperature and steam pressure and were primarily operated by hand. A major change that allowed for safer and more reliable boiler operation was the advent of analog controls in the middle of the 20th century. These systems, however, were not flexible and needed continual human supervision.

2.2 Emergence and Adoption of PLCs.

In the late 1960s, PLCs gained popularity as reliable, reprogrammable industrial automation controllers. Because of its adaptability to a variety of sensors and actuators, simplicity in programming (e.g., ladder logic), and dependability in demanding industrial settings, their usage in boiler systems gained popularity. According to published research, PLCs are widely used for activities including safety interlocking, feedwater control, and burner management. According to studies like Smith et al. (2011), PLCs help to improve operational reliability and decrease system downtime.

2.3 Advancements in AI for Industrial Automation.

Intelligent control in industrial systems is made possible in large part by artificial intelligence. Artificial intelligence (AI) technologies, specifically machine learning (ML) and artificial neural networks (ANNs), are being used to automate difficult decision-making processes, optimize fuel use, and forecast equipment problems. AI systems in boiler automation may learn from past operational data and dynamically modify control tactics, resulting in significant efficiency benefits, claim Wang and Zhao (2017).

2.4 Integration of AI and PLCs.

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2.5 Key Areas of Research Focus Current research is focused on several domains:

Predictive Maintenance: predicting component failures with AI using vibration, temperature, and pressure data.

Combustion Optimization: utilizing AI to control fuel-air mixes in real time for the best possible combustion.

Fault Detection and Diagnostics: putting into practice AI models that are quicker than traditional systems in classifying and reacting to anomalies. Human-Machine Interfaces (HMI): improving operator engagement with voice-activated control systems and smart dashboards.

2.6 Challenges Identified in Literature.

Notwithstanding the advantages, there are difficulties in integrating AI with PLCs. Robust AI model training is hampered by data scarcity, especially labeled fault data. Furthermore, cybersecurity flaws and real-time limitations are commonly mentioned as barriers. The steep learning curve involved in implementing AI solutions in contexts that are typically PLC-driven presents another difficulty.

2.7 Comparative Studies and Benchmarks.

AI-enhanced PLC systems perform better than conventional automation setups in measures like mean time between failures (MTBF), fuel efficiency, and emission control, according to comparative studies conducted across several industries. For example, a 2020 study by Lee et al. found that overall energy efficiency in a textile facility improved by 15% when comparing AI enhanced systems with regular PID controllers.

3. REVIEW METHODOLOGY.

This chapter outlines the approach used to design, develop, and deploy an intelligent automation system for industrial boilers that makes use of artificial intelligence (AI) and programmable logic controllers (PLCs). The strategy combines contemporary data-driven methods with conventional automation procedures to provide a hybrid system that improves boiler operations' operational efficiency, dependability, and flexibility. Requirement analysis, system design, implementation, testing, and validation are all included in the methodology's several stages. Understanding the unique operating difficulties related to industrial boiler systems is the main goal of the methodology's first phase. This entails making sure that safety regulations are followed and precisely controlling variables like fuel input, temperature, water level, and steam pressure.

The following are the main tasks in this phase:

Site Survey and System Study: A detailed analysis of the boiler plant was conducted to understand existing manual or semi-automated processes.

Stakeholder Consultation: To learn more about problems, inefficiencies, and safety hazards, boiler operators, maintenance engineers, and plant managers were interviewed.

PROBLEM STATEMENT DEFINITION:

A problem statement was developed based on observations to address conventional systems' poor response times, inefficient energy use, and deficiency in predictive maintenance capabilities. Functional Requirement Specification (FRS): The necessary features of the system, such as automatic control actions, problem detection, real-time data monitoring, and predictive insights were documented. The basis for a system that blends adaptive intelligence through AI models with deterministic control using PLCs was laid during this phase.

3.3 SYSTEM DESIGN AND ARCHITECTURE DEVELOPMENT.

The automation system's architectural design was the focus of the second phase. The system was designed as a multi-layered architecture with Human-Machine Interfaces (HMI), PLC-based control units, sensor-actuator networks, and AI processing modules.

Fig 5. Automated Boiler Control Human Machine Interface.

PLC Unit:

The resilience and broad industrial use of the Siemens S7-1200 led to its selection based on I/O capacity, communication protocol compatibility, and real-time processing capabilities.

SOFTWARE ARCHITECTURE:

PLC programming environment (i.e., TIA Portal) was used for ladder diagram development.

AI models were developed in Python using libraries such as Scikit-learn, TensorFlow, and Pandas. OPC UA protocol was used for interoperability between PLC and AI modules.

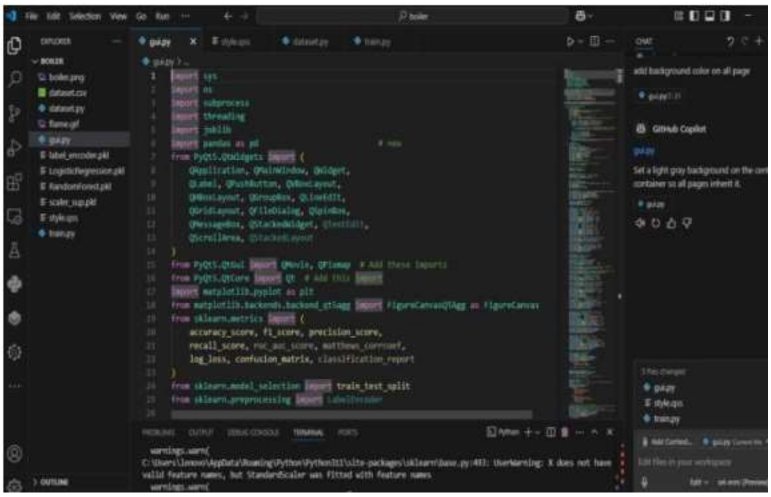

Fig 6. Software Architecture.

Data Flow Diagram:

To show the flow of signals from sensors to PLC, from PLC to actuators, and data transmission to the AI module for processing, a Level 1 DFD was created. This stage made sure the system will be scalable, modular, and able to function in real-time settings.

3.4 PLC PROGRAMMING AND CONTROL LOGIC IMPLEMENTATION.

This phase focused on the development and testing of control logic within the PLC system.

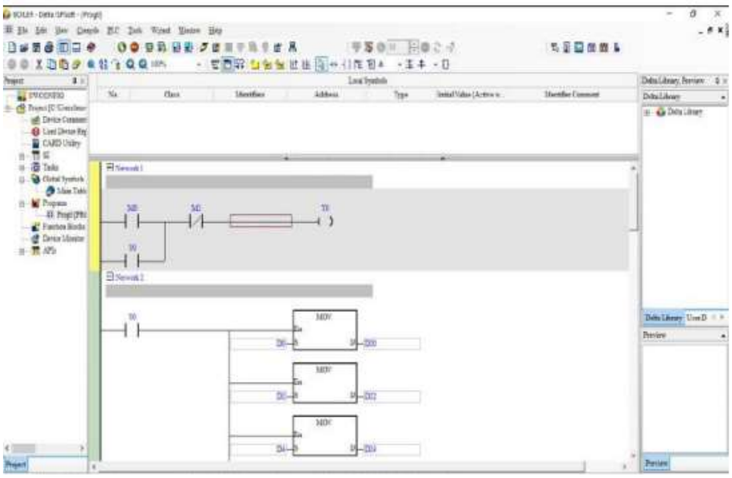

Fig 7. Ladder logic diagram of the program.

The key objectives were to enable autonomous control of the boiler's subsystems and to ensure real-time safety compliance.

PROGRAMMING LANGUAGE:

Ladder Logic was used for ease of visualization and widespread industrial acceptance.

CONTROL STRATEGY:

For closed-loop temperature and pressure control, PID controllers were incorporated into the PLC. In order to initiate alerts or system shutdowns in the event of abnormal situations (such as low water levels or high pressure), interlock mechanisms were created.

SIMULATION AND TESTING:

TIA Portal's PLC simulator was initially used to simulate control logic. To confirm fault management, timing accuracy, and logical correctness, a variety of test scenarios were used. This stage offered a solid foundation of control that runs separately from the AI element.

3.5 AI Model Development.

The PLC manages deterministic control, but AI models were created to offer predictive, adaptive, and intelligent decision-making.

Data Collection and Preprocessing:

The plant's SCADA system provided historical operating data. To deal with noise, outliers, and missing values, data cleaning techniques were used.

Feature Engineering:

Characteristics like fuel usage, ambient temperature, steam load, and pressure change rate were calculated. To determine the main factors influencing boiler performance, correlation analysis was done. Model Selection and Training: To forecast steam output and fuel economy, regression models (such as Random Forest Regression) were trained. For defect detection and anomaly classification, classification models (such as Support Vector Machines and Neural Networks) were employed. A thorough assessment of the model's performance was guaranteed using K-Fold crossvalidation. Deployment: On an edge device linked to the PLC network, trained models were put into use. Rather than taking direct control of the system, the AI module functioned as a supervisor, making suggestions. During this stage, the boiler system was able to make data-driven forecasts that improve decision-making and learn from past trends. 3.6 System Integration For the hybrid automation solution to be successful, the PLC control system and AI module have to be integrated.

Communication Protocols:

The OPC UA server was put into place to facilitate safe and uniform data transfer. For low-latency communication between AI and edge computing units, the MQTT protocol was an optional choice.

Supervisory Control:

The HMI showed the AI predictions, enabling operators to accept or reject suggestions. AI-generated control setpoints were permitted to dynamically alter PLC logic parameters in high-confidence scenarios.

Security and Fail-safes:

Role-based access controls were configured on HMI. Manual override and emergency shutdown options remained active throughout the system lifecycle. This integration ensured a collaborative control model where AI augments but does not replace deterministic logic.

3.7 Testing and Validation.

To ensure system reliability and performance, extensive testing was performed in controlled and operational environments. Functional Testing: Verified that all control logic and AI functionalities performed according to specifications.

Performance Testing:

Metrics like accuracy, F1-score, RMSE, and MAE were used to assess AI models. Response times for PLCs were measured and compared to industry norms.

Stress Testing:

To assess fault tolerance, extreme operating situations were simulated, such as sudden changes in load or sensor failure. Field Testing: conducted under observation in a live boiler system, evaluating operator feedback and practical efficacy. This stage verified the hybrid automation system's scalability and resilience.

3.8 Performance Evaluation and Optimization.

After deployment, ongoing assessment was carried out to see whether boiler performance had improved.
Operational Metrics:

- Reduction in fuel consumption.
- Increase in average steam output.
- Decrease in downtime due to predictive fault alerts.

Feedback Loop:
Operator feedback was collected through surveys and interviews. AI models were periodically retrained with new data to maintain accuracy. This phase ensured ongoing improvement and adaptation of the system in response to dynamic industrial needs.

3.9 Documentation and Training.

Comprehensive documentation was prepared to support future maintenance and upgrades: Training Workshops: Conducted to familiarize staff with AI functionalities, alarm systems, and manual override procedures. Proper documentation and training guaranteed sustainability of the system post-deployment.

3.10 Deployment and Maintenance.

The final system was deployed on-site after successful validation. A structured maintenance plan was implemented, comprising: Scheduled calibration of sensors and inspection of actuators. Periodic testing of PLC logic and communication links. Retraining of AI models every 3–6 months with updated process data. Cybersecurity audits to protect data integrity and prevent unauthorized access.

CONCLUSION AND FUTURE PERSPECTIVE.

PLCs and artificial intelligence (AI) have been integrated into industrial boiler automation, which is a major advancement in the quest for operational excellence and smart manufacturing. This study has thoroughly examined how these technologies, each of which is strong on its own, work together to produce systems that are durable, dependable, adaptable, predictive, and energy efficient. One of the study's main conclusions is that PLCs remain the foundation of industrial control because of their real-time responsiveness, robustness, and deterministic execution. The system as a whole becomes intelligent and able to handle complexity that traditional rule-based automation cannot handle on its own thanks to AI's contribution of higher-order features like pattern recognition, predictive analytics, and self-optimization. Each technology enhances the others in the layered control architecture that results from their combination. The study has demonstrated the feasibility of implementing AI-augmented PLC systems in industrial settings by analyzing boiler types, control requirements, and system design factors. Case studies from industries including food processing, chemical manufacturing, and power generation show observable advantages like lower pollutants, less fuel use, more safety, and better uptime through predictive maintenance. Notwithstanding these benefits, the project also notes a number of implementation issues. These include overcoming opposition to technological change, guaranteeing real-time connectivity between AI modules and PLCs, and requiring high-quality historical data to train AI models. Moreover, the initial investment cost, cybersecurity, and adherence to industry standards continue to be major obstacles to broad adoption. The research anticipates the development of completely autonomous boiler systems in the future, when edge computing, digital twins, and sophisticated human-machine interfaces will allow AI to take on more control duties. In order to narrow the skills gap and train the next generation of automation engineers, industry partnerships and educational institutions must collaborate, and regulatory frameworks are anticipated to change to support and direct these advances. To sum up, this study shows how AI and PLCs can work together to transform industrial boiler automation. Effective design and implementation of such systems can result in industrial operations that are safer, more intelligent, and more sustainable. Although the process of complete integration is still in progress, the groundwork is solid, and intelligent boiler control has a bright and unavoidable future.

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