Plant Information Management System Using OSIsoft PI System: A Case Study of Cilacap Power Plant Units 1 and 2

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Abstract

In the dynamic industrial sector, the ability to combine and manage data from various sources is essential. This study focuses on the utilization of the PI System to integrate operational data from multiple data sources at power plants, facilitating data driven decision making and enhancing operational efficiency. The application of the PI System in collecting data from Distributed Control Systems (DCS) and asset management systems like Maximo is examined, as well as its potential for integrating data from other power plant units. The study utilizes systems analysis methods to understand the potential of data integration in improving operational visibility and control. Findings from testing reveal that effective data integration can extend monitoring and management capabilities, indicating an overall improvement in operational performance. This study contributes to the literature on industrial data management by demonstrating the effective use of the PI System as a comprehensive tool for integrating data from various systems within power plants. It showcases the system's adaptability in enhancing operational decision-making and providing a cohesive platform for real-time performance monitoring. Additionally, the research offers insights into the practical application of systems analysis methods in the context of power plant operations, contributing to the ongoing discourse on digital transformation in the energy sector.

Keywords: Data Integration, PI System, Information Management, Power Plant, Operation Monitoring

I. INTRODUCTION

An Information Management System is a complex infrastructure designed to provide critical information used as a basis for strategic and operational decision making to address the challenges faced by its users [1]. In the era of big data, the Plant Information Management System (PIMS) plays an essential role in collecting, storing, analyzing, and managing large volumes of data from various equipment and systems in an industrial environment. The ability to process and utilize this vast data becomes key in making accurate and timely decisions, ultimately affecting the effectiveness and sustainability of industrial operations.

The primary characteristics of Big Data are found in its massive volume and diversity, which surpass human capability in management, leading to decision making constraints when relying solely on traditional tools and techniques [2][3]. To meet these needs, PIMS adopts advanced technology to integrate, process, and unify data from various sources, implementing in depth data analysis techniques to extract significant insights from complex and often unstructured data sets.

In the industrial world, several leading systems are used as Plant Information Management Systems. One of the most renowned is the Osisoft PI System, which is now part of AVEVA [4]. The PI System has become a standard across various industrial sectors due to its reliability in collecting, storing, and analyzing data. Apart from the PI System, other popular systems include Honeywell Uniformance, which provides advanced real-time digital information for process data and event collection, asset analytics, and visualization [5]. Yokogawa Exaquantum, capable of collecting data from all aspects of a process and converting it into easy to use, high value information that can be widely distributed [6]. Each of these systems offers different features for monitoring, data collection, analysis, and reporting. The choice of the most suitable system will depend on specific needs, budget, and existing technological infrastructure of the company or industrial facility.

In industries like the Cilacap Steam Power Plant Units 1 and 2, PIMS is utilized to monitor operational conditions and electricity production. In its operations, Cilacap power plant relies on various data sources such as database systems, SCADA, manual input, software applications, actuators, sensors, and asset management systems. Although each data source comes from different manufacturers, the PI System can be a reliable solution. The primary reason for this choice is the flexibility of the PI System in integrating with diverse devices and systems, as well as its sophistication in managing industrial data from the stages of collection, analysis, visualization, to distribution. Globally, this system has gained the trust of major industries: 25 of the top 25 pharmaceutical companies, over 1000 electric utility companies, and 75% of the world's crude oil production utilize it. Moreover, 9 out of 10 top mining companies also choose the Osisoft PI System [4]. The global achievements of the Osisoft PI System have encouraged companies in Indonesia, especially in the oil and gas sector, to start integrating it into their operations.

In the dynamic industrial sector, the integration and management of data from varied sources are imperative. While previous studies have established the use of PI Systems in various sectors [7][8][9][10], they have not thoroughly explored the integration of systems such as Distributed Control Systems (DCS) using Foxboro and Maximo for asset management. This study extends the current knowledge by focusing on the integration of operational data from these specific systems, as well as introducing a novel approach of incorporating mobile application data retrieval from the PI System. The systems analysis methods employed offer a comprehensive understanding of the data integration's potential to enhance operational visibility and control. Findings indicate that a well-integrated system broadens the monitoring and management capabilities, resulting in improved operational performance. With the inclusion of mobile applications, the research highlights the extended flexibility of the PI System as a monitoring tool, enabling data access from remote locations and contributing to the literature on mobile applications in industrial system integration. The purpose of this research is to elucidate the enhanced capabilities and benefits of integrating these particular systems into the PI System, thereby supporting more efficient and informed decision-making processes.

II. RESEARCH METHODOLOGY

In this research, a practical and organized method was used to gather the information. The focus was on how the PI System works alongside other technologies at the Cilacap Steam Power Plant to manage data.

The process began with observing the plant's operations and collecting information. This involved looking closely at how different data systems are used together and how the staff interact with them. The aim was to see firsthand the flow of data and how systems like Foxboro and Maximo are connected in the day-to-day work.

The next part was to sort through the collected data to spot trends and key points, especially around the integration of different systems. This was an important step to figure out the benefits and any issues with how things are currently set up.

Developing a mobile app to work with the PI System was also a crucial step. This allowed for checking how mobile technology might help staff see and use operational data on the go. Testing this app provided real, hands-on insights.

Overall, the approach taken in this research was like a guide, helping to navigate from the first steps of data collection all the way to understanding what the data means, all with the aim of improving how the plant runs and uses its data.

Following the data analysis, attention was then turned to the architectural framework of the system. This segment of the research delves into the structured design that enables various technologies to communicate seamlessly within the Cilacap Steam Power Plant. By dissecting the system architecture, the study reveals the interconnected nature of data pathways and the role they play in the plant's operational integrity.

Subsequent sections will explore the communication protocols that form the backbone of data exchange between the PI System, Foxboro, and Maximo. Understanding these communication channels is crucial, as they are the lifelines that transmit critical operational data.

Lastly, the research will provide an overview of the PI software itself, highlighting its features and capabilities. This will include an analysis of how the software processes, manages, and visualizes data, culminating in a discussion of its application in the mobile app developed for the plant's staff. Each of these components—architecture, communication, and software—is integral to the overall data management ecosystem and contributes to the plant's operational efficiency.

A. System Architecture

Cilacap Steam Power Plant Units 1 and 2 are electricity generation facilities with a production capacity reaching 2×300 MW. Each power generating unit in these facilities is equipped with an independently operating Distributed Control System (DCS). The DCS, using Schneider Foxboro, plays a crucial role in controlling the three main systems of power generation: the boiler, turbine, and generator. In addition to these primary systems, there are various supporting subsystems, including but not limited to the Lube Oil System, Cooling Water System, Air and Flue Gas System, Steam Water System, Electrical System, and others. These subsystems are equally important in ensuring the smooth process of electricity production.

Beyond the main operational systems, Cilacap Power Plant is also supported by a power generation asset management system known as Maximo. This system is pivotal in managing existing assets to maximize productivity and efficiency in asset management.

To comprehensively monitor the processes at Cilacap Power Plant Units 1 and 2, the Osisoft PI System has been adopted as the primary platform. This system integrates data from the DCS system and subsystems as well as from other supporting sources, enabling comprehensive data collection and processing. However, data from sensors, actuators, and DCS equipment controls cannot be directly accessed by the PI System. To address this, DCS workstation computers function as gateways, retrieving data from field instruments and forwarding it to the PI System.

Within the PI System infrastructure, there are two main servers: the PI Server PIMS and the PI Server Coresight. The PI Server PIMS is equipped with various functional components such as the Interface/Connector, which collects data from various sources, Analytics for processing and analyzing data, Asset Framework that provides a structure for asset data and information, and Data Archive for storing historical data. On the other hand, the PI Server Coresight plays a role in providing data visualization components, enabling users to view and understand data graphically through a web server. The components and functions of the PI System as a whole can be illustrated in Figure 1 presented in the document.

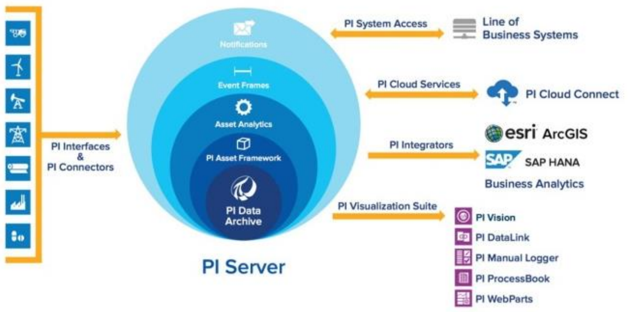

Figure 1. PI System Component

In the framework of Cilacap Power Plant Units 1 and 2, data collection serves as the backbone of the information system. The PI Server PIMS plays a central role in this process, capturing, processing, and storing data originating from the Distributed Control System (DCS) and the asset management system. This data is then integrated with additional information, such as meter readings from ION power meters and manual inputs, creating a comprehensive information repository. The data collected from the DCS includes essential values from sensors and actuators in the field. To ensure that the PI Server PIMS can connect with this equipment, Cilacap Power Plant Units 1 and 2 have implemented a specific architecture designed to support an efficient yet secure flow of data. This architecture is depicted in Figure 2, illustrating how the system components are connected and interact, ensuring data integrity and availability for effective, secure operations and informed decision making.

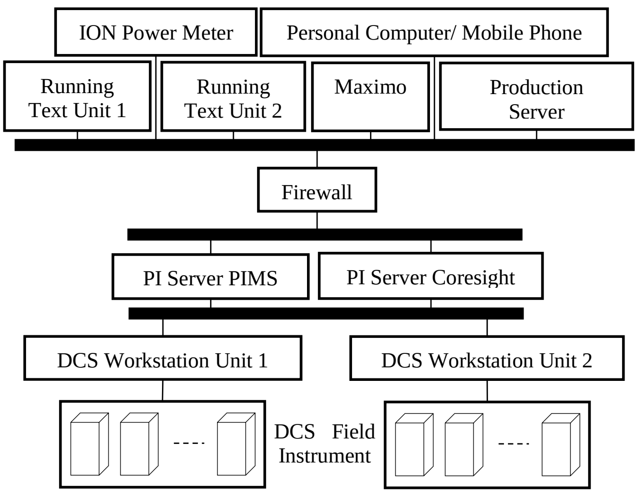

Figure 2. The design of the PI System Architecture in Cilacap Power Plant Units 1-2

B. Communication

Inter system and device communication within the information technology infrastructure is a critical aspect that determines the success of data integration. The PI System, used by Cilacap Power Plant Units 1 and 2, offers extensive capabilities in supporting various industrial communication protocol standards. These protocols facilitate the exchange between the PI System and other devices in the industrial network.

a. OPC (OLE for Process Control)
As the backbone of communication, OPC enables reliable real-time data exchange between automation devices. Recognized as an industry standard, OPC simplifies interactions between various control and monitoring systems, eliminating the barriers often encountered in communication processes between different devices [11].

b. WEB API
Utilizing modern web technology, WEB API allows web based applications to interact with the PI System, extending accessibility and enabling data usage through a variety of distributed applications.

c. JSON (JavaScript Object Notation)
As a lightweight data interchange format, JSON eases the transfer of data between servers and web applications, enhancing integration with platforms utilizing web and mobile technologies.

The communication used in the data retrieval process from PI Server PIMS to DCS employs the OPC protocol. OPC is a series of standards developed through collaboration with several leading industrial automation suppliers. The primary goal of OPC is to define a uniform interface that can be used with any organization's software package or custom software. In other words, OPC aims to create a consistent communication standard that can be used with various software in the automation industry to facilitate integration and interoperability [11].

Before being transmitted via OPC, data from the DCS is first formatted by FSGateway (Factory Suite Gateway). FSGateway is an application that acts as a protocol converter, used to connect clients and data sources communicating using different protocols. In other words, FSGateway functions as an intermediary that allows various devices and applications to communicate even if they use different data access protocols. This facilitates integration and data exchange between various systems used in industrial or automation environments. This communication process, from data retrieval by PI Server PIMS to the DCS workstation via the OPC protocol, is illustrated in Figure 3.

Figure 3. OPC Communication

Next, at the DCS workstation, Figure 4 illustrates the configuration of FSGateway, showing how this application is set up to provide effective communication between different systems.

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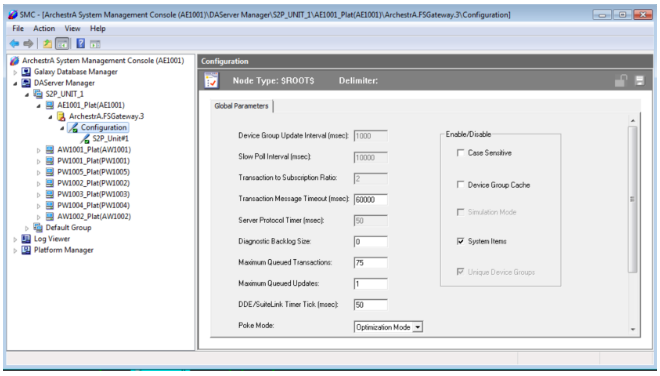

Figure 4. FSGateway DCS Workstation

Besides using OPC, the communication used to connect the PI System PIMS with the Production Server is through the Web Application Programming Interface (API). An API is a set of rules and protocols that allows various applications and systems to communicate with each other over a network, such as the internet. APIs often use standard communication protocols such as HTTP (Hypertext Transfer Protocol) or HTTPS (Hypertext Transfer Protocol Secure) to send requests and receive responses. Data is typically formatted in JSON (JavaScript Object Notation) or XML (Extensible Markup Language).

JSON (JavaScript Object Notation) is a lightweight, easy to read, and easy to write data interchange format. It is used for sending and storing data in a format that is human readable and can be interpreted by various programming languages [12]. An example of data retrieval in JSON format is shown in Figure 5.


```
{
    "Value": {
      "Timestamp": "2022-08-04T10:55:16.6850128Z",
      "Value": 169.8,
      "UnitsAbbreviation": "MW nett",
      "Good": true,
      "Questionable": false,
      "Substituted": false
    }
}
```


Figure 5. JSON Format

The ability to utilize both OPC and Web API signifies the flexibility and suitability of the technology employed by the Cilacap Power Plant Units 1 and 2 in addressing various data communication needs. This reflects a comprehensive approach in building a technology infrastructure capable of facing the challenges of complexity and scalability demands required by modern industrial operations.

C. PI System Software

The software used by the PI System to communicate with the OPC client is the PI ICU (Interface Configuration Utility). PI ICU acts as an interface that connects with the OPC server and performs data retrieval. The following are applications found in the PI System (Figure 6).

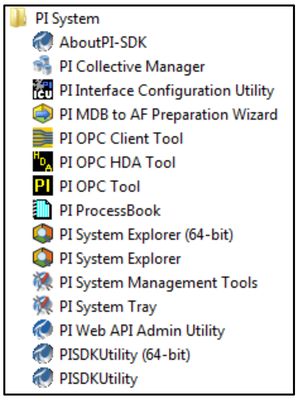

Figure 6. PI System Tools

Another PI System application used is the PI System Management Tools (PI SMT). The PI System Management Tools (PI SMT) are a critical component in the PI System ecosystem, offering a range of utilities to ensure that the data infrastructure operates at optimal efficiency. As a feature rich application, PI SMT provides extensive capabilities for technicians and system administrators to perform initial configurations, which include creating and setting up tags, as well as determining and implementing security policies. This tool also enables continuous monitoring of system health, ensuring that all aspects of the PI System, from servers and databases to connectors and interfaces, are running smoothly and free from operational issues. Figure 7 shows the interface of PI SMT.

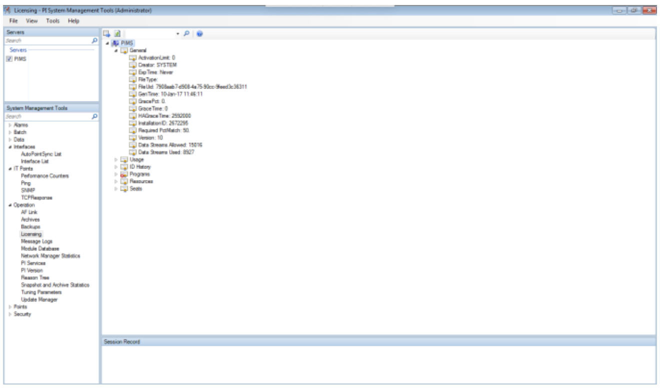

Figure 7. PI SMT

In terms of data management, PI SMT provides an intuitive interface for accessing, managing, and manipulating data stored in the PI Data Archive, enabling users to effectively manage both historical and real-time data. Security is another critical aspect addressed by PI SMT, allowing for the setting of stringent access controls and security protocols to protect data integrity. Additionally, PI SMT simplifies the processes of backup and recovery, ensuring that crucial data is protected and can be restored in cases of data corruption or loss.

Next, as an integral application of the PI System tool suite, is the PI System Explorer. PI System Explorer facilitates more intuitive and centralized asset and data management. Alongside PI ICU and PI SMT, the PI System Explorer application is also used. This application is designed to provide a graphical user interface (GUI) that allows users to access, configure, and manage data and asset information stored in the PI Asset Framework. With PI System Explorer, managing attributes such as setting values, units, and metadata can be done centrally, allowing for efficient updates and modifications. Additionally, PI System Explorer's data integration capability enables the merging of data from various sources.

III. RESULTS AND DISCUSSION

The PI System was established through a collaborative effort between the plant's ownership and Foxboro (Schneider Electric). Engineers from both entities worked jointly to design a system tailored to the power plant's specific requirements, culminating in the successful installation of the PI System. This collaborative phase was crucial in ensuring that the system architecture not only integrated seamlessly with the existing infrastructure but also met the operational needs of the plant.

Subsequent to the PI System's implementation, the power plant's management engaged engineering consultants to further refine the system. These experts were tasked with creating, modifying, and verifying the complex formulas used within the PI System to calculate and assess the power plant's performance. This step was pivotal in enhancing the accuracy and reliability of the performance data generated by the system, thereby providing a solid basis for operational decisions and strategies aimed at optimizing efficiency and productivity.

This meticulous approach to developing and refining the PI System underscores the detailed methodology mentioned in the previous chapter. The results and discussions presented in this chapter draw upon the data captured through these enhanced systems, offering a robust analysis of the plant's operational dynamics and the PI System's role in improving overall performance.

As per the system architecture shown in Figure 2, there are two computers that are part of the PI System, namely the PI Server PIMS and the PI Server Coresight. PI Server PIMS functions to perform data retrieval, storage, and calculation. Meanwhile, PI System Coresight acts as a web server for visualization and provides Web API services. Data retrieval from PI System PIMS to the DCS workstation uses the OPC protocol. The DCS workstation will act as an OPC server and the PI System PIMS as an OPC client. For DCS values to be accessed by the OPC client, configuration is required by registering these tags on the FSGateway of the DCS workstation (as shown in Figure 3).

To ensure that data from DCS and the Maximo asset management system can be monitored from mobile and web applications, it is necessary to ensure the PI system can connect with the DCS, Maximo, and end users.

A. OPC Communication Testing

Communication testing with the DCS workstation is conducted using the OPC client application on the PI Server PIMS. Figure 8 depicts the steps involved in testing communication and data retrieval.

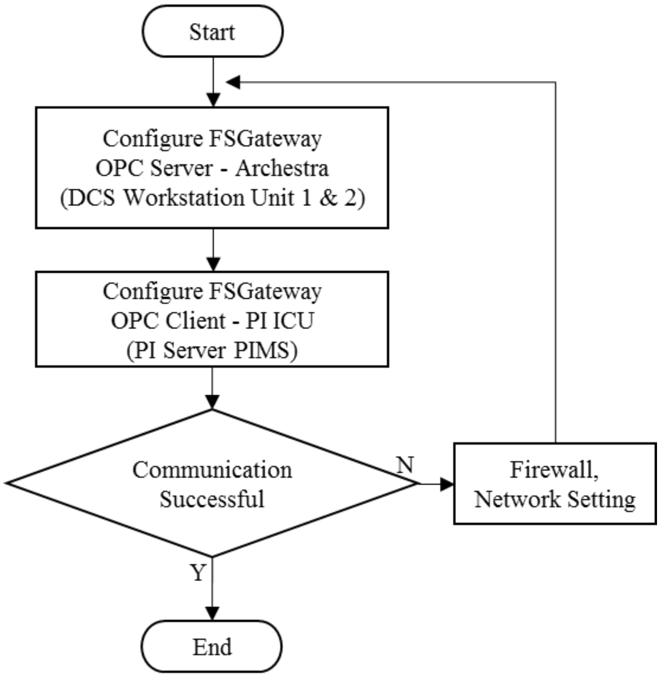

Figure 8. OPC Setting Workflow

Figure 9 shows that the OPC Client is already connected to the OPC server through the FSGateway converter.

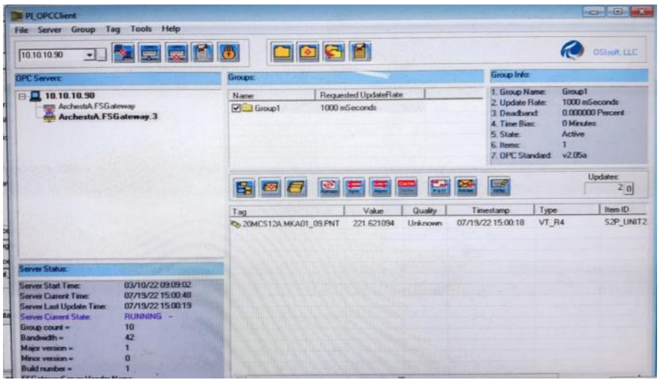

Figure 9. Connection Test OPC Server-Client

To facilitate data retrieval from the OPC Server, it is necessary to register the tag names of the equipment allowed for data extraction in the OPC Server's device list (DCS workstation). Figure 10 represents the list of equipment tags whose data can be retrieved.

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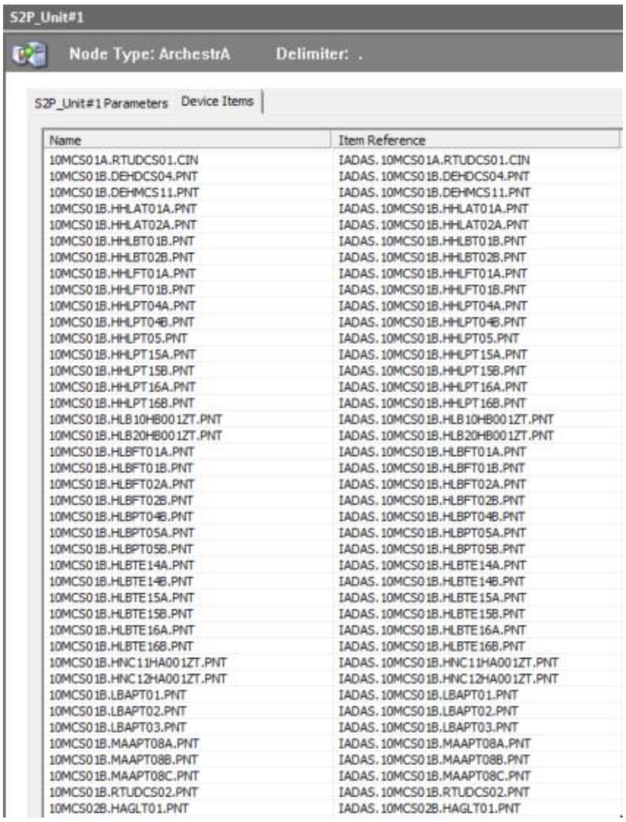

Figure 10. OPC Item Devices List

The OPC client (in this case, the PI System PIMS) also needs to be configured to communicate with the OPC server. Within the PI System PIMS, the PI ICU is utilized to configure OPC communication. The same converter application (FSGateway) is also used in the PI System PIMS to enable communication with the FSGateway on the DCS workstation side (Figure 11).

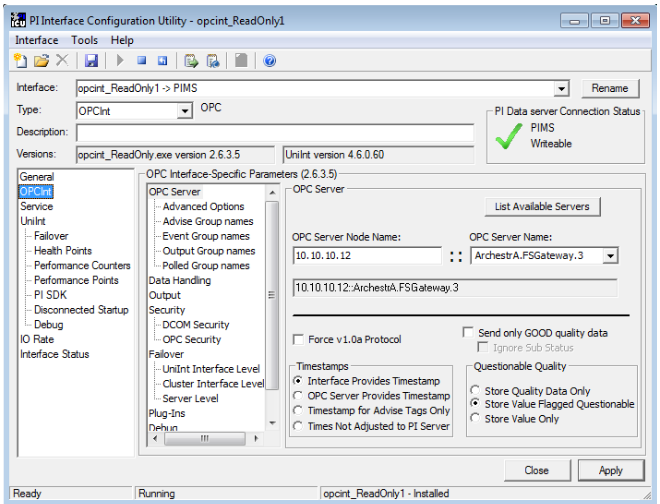

Figure 11. FSGateway PI Server PIMS

The interval for data retrieval can be adjusted according to user needs. The setting of the interval used at the Cilacap Power Plant is shown in Figure 12 under the scan frequency section.

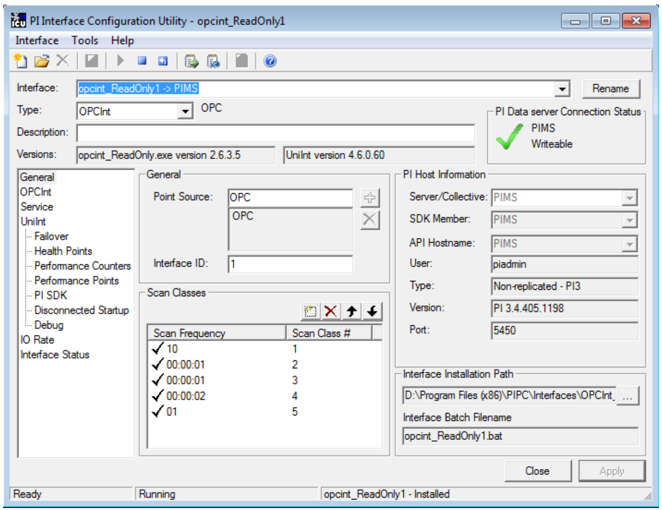

Figure 12. OPC Data Interval

B. Data Point Testing

Once the OPC communication path is established and values can be read by the client, these values need to be registered as PI Points so they can be used for other purposes. If storage is required, the data will be entered into the historical database. This process can be carried out using the PI SMC application. Figure 13 shows the flowchart for setting up data points to ensure successful retrieval

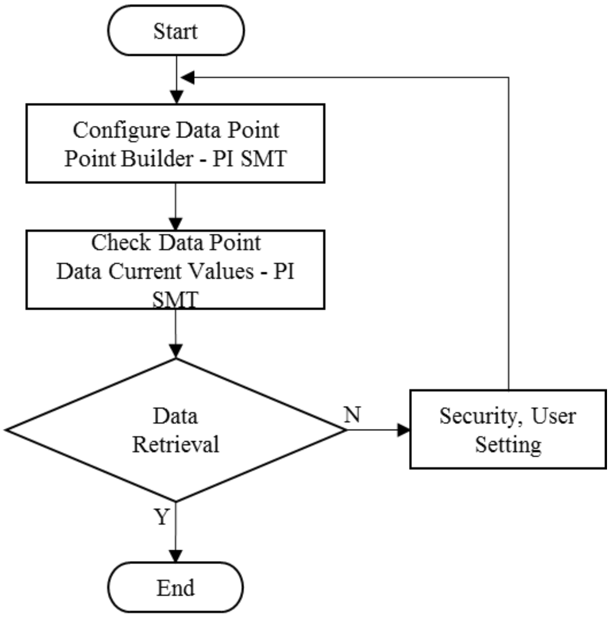

Figure 13. PI Data Point Test

C. Testing Query to the Maximo Database

The asset management system (Maximo) is also connected to the PI System PIMS through a database connection. Maximo stores its data using an Oracle database. The PI

System has the capability to communicate with many types of databases, including Oracle (Figure 14). The PI System queries Maximo to obtain the desired data from Maximo. Data is received by the PI System in the form of a table.

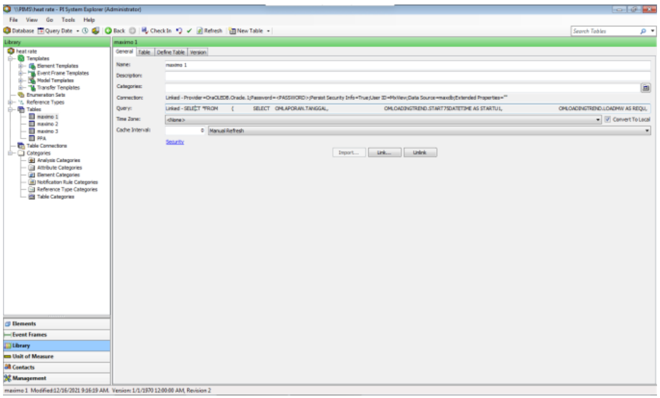

Figure 14. Query Setting for Maximo Database

D. Web API Communication Testing

The Production Server acts as a data provider for IOT. It retrieves data collected by the PI System through the Web API, which is one of the features of PI System Coresight. Data requests are sent to the PI Web API via HTTP and are responded to by the PI System Coresight by sending the requested data. This data is transmitted in JSON format.

E. Effectiveness of Using the PI System

The use of the PI System at the Cilacap Power Plant Units 1 and 2 plays a crucial role, particularly in the process of calculating the heat rate. This process requires inputs from hundreds of values obtained from sensors installed in turbines and boilers [13]. Not dependent on sensor data alone, this calculation also involves other variables sourced from the asset management system (Maximo) and manual input by operators. The PI System enables the real-time acquisition of all these variables, which is a vital step in this process. Furthermore, the system is also capable of calculating the heat rate in real-time, allowing for more effective and responsive energy efficiency management to operational condition changes. With this capability, the PI System not only improves the accuracy of heat rate calculations but also provides valuable insights for more informative and timely decision making in the operational management of the power plant.

The manual process (Figure 15) conducted by humans has several disadvantages compared to using the PI System, including:

1) Manual processing requires longer data collection time, especially if there are many variables from various sources.
2) The probability of errors in data processing is higher.
3) It is not possible to process and analyze data in real-time.
4) There is a dependence on personnel.

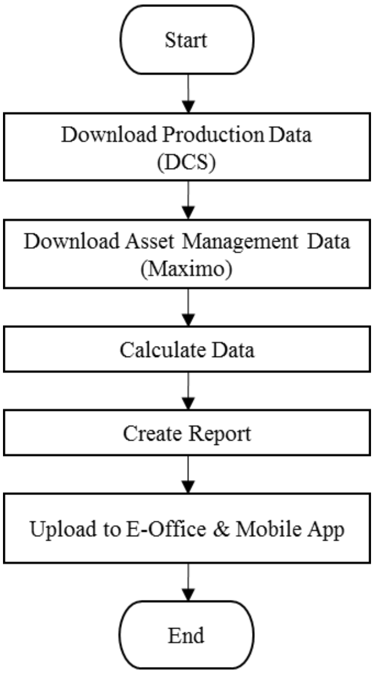

Figure 15. Flowchart for Obtaining Heat Rate Value

Mobile applications essentially retrieve data from the Production Server. These mobile apps display the condition of the power plant and can be accessed via the internet. Real-time load and set points are displayed in the application as shown in Figure 16.

Figure 16. Mobile Application Interface

In addition to monitoring capabilities through mobile applications, Cilacap Power Plant Units 1 and 2 also utilize a web based visual platform that can be accessed via an internet browser. This approach provides a more flexible and accessible way to view data and analyze the performance of the power plant. Figure 17, for instance, displays one of the many data sets available on the web interface. This data is not just a raw representation but is rather the result of calculations and analyses performed by the PI System.

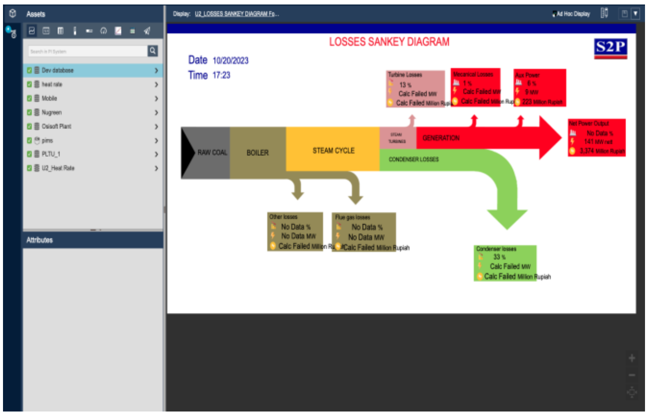

Figure 17. Web Application Interface

The data presentation in the PI System at Cilacap Power Plant is designed to facilitate user understanding of the plant's performance comprehensively. Through the use of intuitive and informative data visualizations, as seen in Figure 18, users can quickly identify trends, patterns, and areas that require special attention or maintenance. These visualizations not only display raw data but also transform it into easily understandable graphs, diagrams, and dashboards, thereby facilitating rapid and accurate interpretation.

This advantage is significant for technical staff and management, as it enables them to make decisions based on in depth and timely data analysis. These decisions can range from scheduling routine maintenance to rapid response to emergency conditions, thus enhancing operational efficiency and plant reliability.

The integration of the PI System into a web environment extends its accessibility, not limited to on site staff but also available to decision makers at various organizational levels. With web access, critical data can be accessed from anywhere, accelerating the decision making process and enhancing collaboration among teams. It also allows for broader monitoring, including by external parties such as regulators or business partners, which can increase transparency and accountability.

In the context of plant management and operations, the added value of this tool is significant. The PI System not only facilitates the monitoring of performance and maintenance of facilities but also supports strategic decision making for continuous improvement in efficiency and productivity. With the PI System, there is an expectation of improved reliability, availability, maintainability, and safety in power generation [14].

In addition to the robust integration capabilities demonstrated between the PI System, Foxboro's DCS, and Maximo's asset management within this study, it is worth noting the potential for utilizing alternative communication protocols such as Modbus [7]. This protocol presents a valuable opportunity for extending the PI System's data collection capabilities to include Programmable Logic Controllers (PLCs) and other devices that using Modbus for communication. Such flexibility significantly enhances the system's utility by broadening the range of data sources it can interface with.

Moreover, the PI System's capacity to process and organize data offers an intriguing prospect for its role in broader operational ecosystems. Data that have been aggregated and refined within the PI System can serve as a valuable input for other systems, facilitating further analysis and processing. This functionality positions the PI System not merely as a data integration tool but as a critical data repository [15] that can support complex analytical tasks. The implications of this are profound, suggesting that with appropriate development, the PI System could evolve into a cornerstone of a smart system architecture [16].

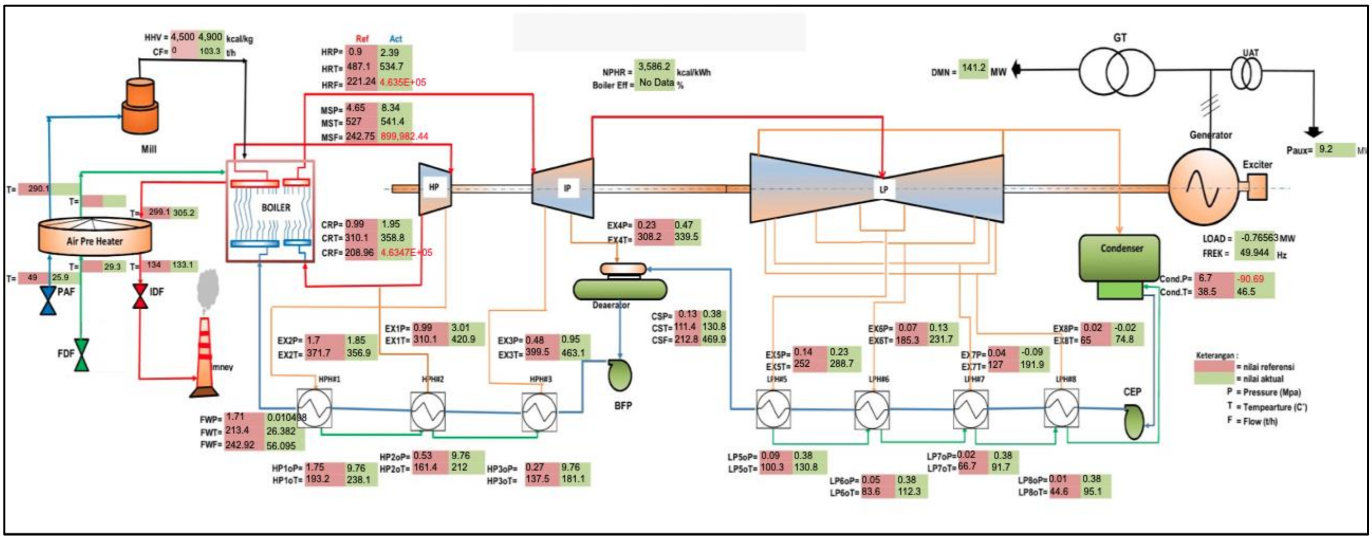

Figure 18. Plant Information Management System

IV. CONCLUSION

The discussion underscores the PI System's robust flexibility and integration capabilities with various industrial control and asset management systems. Notably, it demonstrates the system's adeptness in connecting with Foxboro's Distributed Control Systems (DCS) and the Maximo asset management system, utilizing the OPC protocol to ensure seamless communication and data synchronization. This connection enables the real-time collection and access of operational information, significantly enhancing the management of operations and assets. The ability of the PI System to interface effectively with both Foxboro and Maximo addresses the critical problem identified in the background, proving it as a pivotal solution for comprehensive data integration across different technological platforms within industrial settings. Thus, the PI System stands out as an essential tool for asset and resource management, offering a unified view of operational and asset-related information through its extensive integration capabilities.

Furthermore, the PI System can retrieve and transmit data to IoT servers using an efficient PI Web API, leveraging the JSON format for lightweight and easily integrated data exchange. This format is particularly suitable for web and mobile applications, allowing data to be accessed and monitored from anywhere, including via smartphones, offering ease in remote monitoring and high operational mobility.

With the extensibility of the PI System, the prospect of integrating with other units of Cilacap Power Plant becomes feasible, which will extend the scope of operational monitoring to more generating units. Such integration will not only enhance the visibility of overall plant performance within a uniform platform but will also enrich analytical capabilities and strategic decision making. This enables these plants to not only monitor performance locally but also provides the ability to conduct surveillance and maintenance remotely, enhancing efficiency and responsiveness to unforeseen events. Thus, the utilization of PI System technology can become the foundation for broader digital transformation in the energy generation sector, strengthening the existing information infrastructure and leading to more integrated and automated operations.

One notable limitation identified in this study is the licensing issue related to the number of data tags that can be registered within the current PI System at the Cilacap Power Plant. This constraint has restricted the inclusion of all possible parameters from the DCS and Maximo systems, thereby limiting the scope of data integration and analysis capabilities.

Given the PI System's central role in integrating various data sources, it is imperative to ensure robust network security measures are in place. Future research should focus on enhancing the system's security framework, particularly in areas such as virus and malware protection, and defenses against potential hacking attempts. A well-protected PI System is essential for maintaining the integrity and reliability of data management processes, especially when dealing with a wide array of data sources across critical infrastructure.

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