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EVALUATING THE DIGITALIZATION CAPABILITY AND DISPLAY OF KPIS FOR TWO FERTILIZER PLANTS OF PETROVIETNAM

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Summary

The study partially funded by the Vietnam Oil and Gas Group (Petrovietnam) assesses the infrastructure, OT/IT systems, and data handling at two fertilizer plants. Although well-equipped with automation control technology, the plants lack seamless integration, connectivity, and encounter limitations in communication between systems. To address these issues, the study advocates for the integration of digital technology, emphasizing its potential for enhancing efficiency, facilitating optimal management, and guiding strategic direction. Following an assessment of infrastructure, key performance indicator (KPI) system requirements, and data management, the study proposes an initial application of digital technology to link KPI displays. The outlined scope, initial costs, investment phases, and implementation schedule indicate a total initial investment of around VND 37 - 39 billion, accompanied by annual maintenance costs ranging from VND 3.7 to 4.1 billion. Expected economic and social benefits involve improved management at both Petrovietnam and plant levels through the KPI system, with an estimated energy cost savings of 1%, equivalent to roughly VND 44.6 billion. The project aims to position the fertilizer plants and Petrovietnam as leaders in technology, contributing to sustainability and enhancing their global industry reputation.

Key words: Digital transformation, key performance indicator, fertilizer plant, operational production.

1. Introduction

Industry 4.0 - also called the Fourth Industrial Revolution or 4IR - is the next phase in the digitization of the manufacturing sector, driven by disruptive trends including the rise of data and connectivity, analytics, human-machine interaction, and improvements in robotics. Industry 4.0 and digital transformation are marking a significant milestone in the industrial sector, particularly in the oil and gas. Advancements in artificial intelligence, the Internet of Things (IoT), machine learning, and smart automation have presented new opportunities and challenges for businesses in this sector [1 - 3]. By applying Industry 4.0, integrating these technologies into the production process, the plants can leverage digital solutions for safety management, production optimization, and asset management to enhance performance and reduce costs [4, 5].

The trends in the 4IR and digital technology have gradually influenced the operational and managerial practices of Petrovietnam and its affiliated companies. To bolster competitiveness, especially in ensuring the consistent operation of plants, Petrovietnam is strategically planning to integrate digital technologies progressively, aiming to establish smart factories in the foreseeable future.

The two ammonia plants funded by Petrovietnam, namely Phu My and Ca Mau fertilizers were constructed during the Third Industrial Revolution. Consequently, there is a need to explore the transition to implement technology for enhanced management, monitoring, and production optimization - not only technologically viable but also cost-effective. This transition improves managerial efficiency and fosters the exchange of experience and

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information among plants. Despite the advantages embedded in the current infrastructure and management framework, there exist certain limitations, including: (i) The system is geared solely towards internal management with a lack of external connections and information sharing, particularly with Petrovietnam and its managed plants; (ii) The synchronization of information technology application in control and automation systems within the plants is not uniformly high; (iii) There exists variability in investment levels, types, objectives, and timelines.

Furthermore, the current operational framework of both fertilizer plants does not incorporate key performance indicators (KPIs) for detailed monitoring and controling at each stage or production area. Instead, they rely on a set of analogous indicators termed "Operational consumption standards" for the entire plant, which are not fully digitized. On a monthly and annual basis, data collection occurs, and this information is inputted into an Excel spreadsheet known as "Overall specific consumption standards" for reporting or planning purposes.

Therefore, it is crucial to develop calculations for KPIs in production operations at various levels, as well as to standardize and synchronize the two plants. Integration and enhanced display capabilities are essential for monitoring, tracking, controlling production operations, and supporting decision-making processes for the leadership of Petrovietnam and its affiliated units.

For the oil and gas industry, especially in the operation of oil refineries and fertilizer plants, various information technology/operational technology (IT/OT) licensors such as Honeywell, Yokogawa, Dassault Systems, Siemens, ABB, etc., provide solutions to satisfy basic purposes such as improving productivity, reducing production costs, saving energy, optimizing plants, and enhancing reliability. They can be categorized into several main areas such as safety management, asset management, production optimization, management solution, etc., as illustrated in Figure 1 [6 - 9]. These

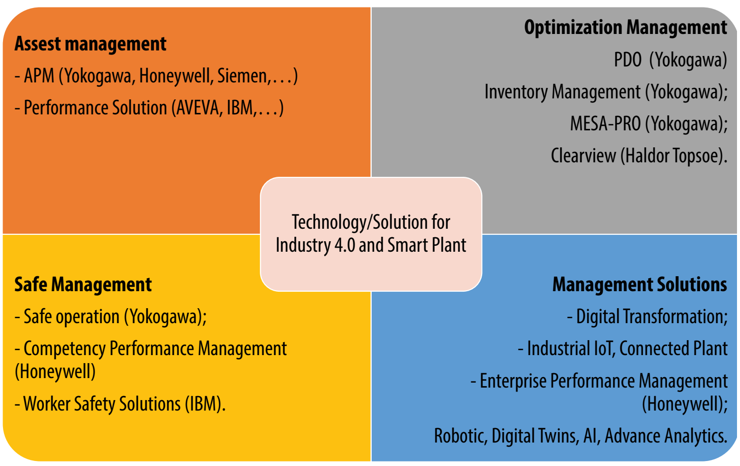

Figure 1. *Several technologies/solutions for fertilizer plants forward Industry 4.0 and smart operation.*

solutions encompass various small packages and specific technologies depending on each plant's requirements and applicability. The main solutions are software applications, and the licensors will evaluate the need for hardware supplements based on each plant's infrastructure to implement the solutions. The solutions are implemented separately, not requiring the plant infrastructure to reach the level of Industry 4.0 [10, 11].

As a result, Petrovietnam has assigned Vietnam Petroleum Institute (VPI) to implement the task "Research on the feasibility of applying digital technology in conjunction with software for the online management, monitoring, and control of KPIs related to the production operations of the two fertilizer plants of Petrovietnam". This initiative aims to align the two fertilizer plants with development trends, assess and enhance their management processes with plans to further extend this approach to other Petrovietnam facilities. In this paper, VPI focuses on evaluating the infrastructure (OT/IT) of the two plants, examining connectivity, digitization of KPIs, as well as data management to improve the management and monitoring capabilities of Petrovietnam and its two units. The methodology for deployment, the KPIs determination and results will be presented in a separate paper.

2. Objectives and methodology

As mentioned earlier, the primary aim is to define KPIs related to production operations, digitization, and smooth connectivity for effective management and monitoring of the plants. The overall methodology and solution for this project are illustrated in Figure 2. For Petrovietnam, the end-user, it is essential that the chosen KPIs set is consistent with current industrial development trends, emphasizing connectivity and online display capabilities. After implementation, Petrovietnam personnel can anticipate the ability to remotely monitor plant activities and receive automatic reports from plants while sitting at the headquarters.

To initiate the implementation, a thorough survey and assessment of IT/OT infrastructure,

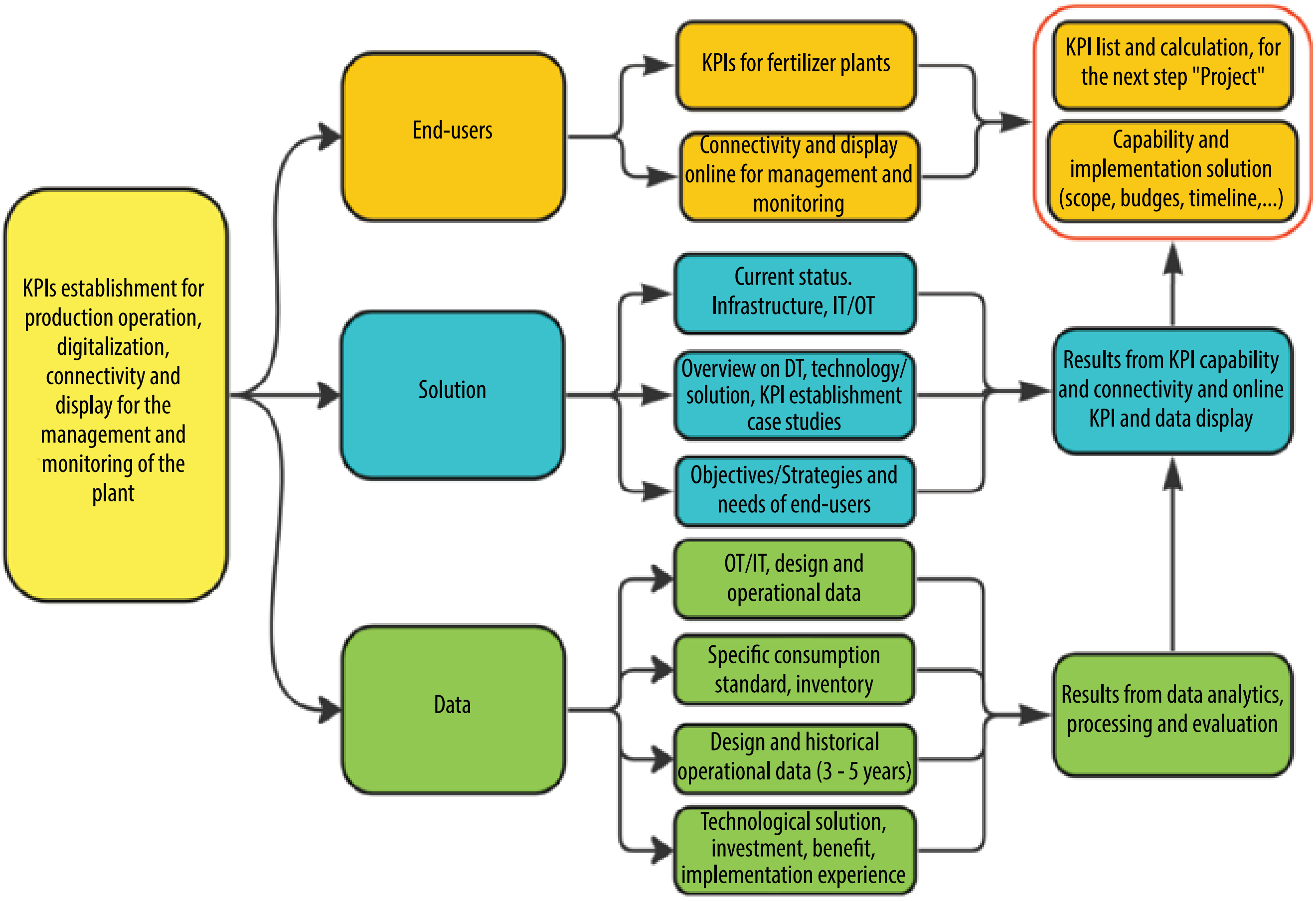

Figure 2. *The overall methodology and solution for this project.*

plant operations, and existing consumption standards at the plants are imperative. Collaboration with various OT/IT licensors and fertilizer production complexes such as PUPUK fertilizer plants (Indonesia) is vital to gain insights into technology/solutions for digital transformation, KPIs setup, best practices, and the status of technology/solution implementation in other plants. This collaboration aligns well with Petrovietnam's goals and directions. The data required to collect and evaluate encompass:

- IT/OT data, design data, operational data, specific consumption standards, maintenance, and inventory of supplies.

- Last 3 - 5 years' operational (process) data, digitalization solutions/technologies, etc.

Upon gathering this data, the subsequent steps involve analyzing and processing the information, assessing the feasibility of implementing KPIs, and exploring the potential for digitizing data connectivity. The result of this task will be a set of KPIs algorithms and data, facilitating the progression to the next phase, which includes "Project procurement". As mentioned above, the KPIs establishment and algorithms will be shown in another paper.

3. Current status of Petrovietnam's fertilizer plants

Petrovietnam operates two fertilizer production plants situated in Phu My and Ca Mau. Phu My Fertilizer is located in Phu My Town, Ba Ria - Vung Tau province. Ca Mau Fertilizer is situated in the southwestern province of Vietnam. Commencing operations in 2004 (Phu My) and 2012 (Ca Mau), both plants actively contribute to the market with a significant volume of urea, NPK, and other products like CO_2, UFC85, etc., further bolstering the agricultural development and economic progress of Vietnam. At present, these plants have control-automation systems that are predominantly installed, as outlined in Table 1.

The elements within a control-automation system, both software and hardware, communicate and exchange information across the network through a set of protocols. Broadly speaking, the communication protocols employed in both fertilizer plants are comparable and include ethernet, Modbus, OPC, Profibus, foundation Fieldbus, and hardwire. For a detailed overview of the primary signaling protocols utilized by each system in the two fertilizer plants, please refer to Table 2 and Figure 3.

***Table 1.** Main hardware and software installed in Phu My and Ca Mau fertilizers. Source: PVCFC, PVFCCo.*

No.	Hardware/Software	Function	Phu My Fertilizer's license	Ca Mau Fertilizer's license
1	Distributed control system (DCS)	Manage the entire technological process of the factory	Yokogawa VP	Yokogawa VP
2	Emergency shutdown (ESD)	Intervene in the operation of the plant to protect before a technological incident occurs	Yokogawa Prosafe Triguard SC300E	3 Triconex ESD systems
3	MPS/ Machinery managing system (MMS)	To manage several dynamic equipment in the factory	MPS: GE Bently Nevada MMS: System 1	MPS: GE Bently Nevada MMS: System 1
4	Advanced process control (APC)	For optimization of ammonia unit	Honeywell	Honeywell
5	Information Management System (IMS)	Keep track of several technology segments	IMS - Siemens system was put into operation in 2007. à Replaced IMS with self-built PMIS system 2020	Using PI (Aveva) in 2023
6	Computerized maintenance management system (CMMS)/Reliable centered maintenance (RCM)	Maintenance and maintenance management	Ivara - Siemens	RCM method
7	Enterprise resource planning (ERP)	Computer software for business administration	Oracle ERP	SAP ERP
8	Burner management system (BMS)	It is a form of safety PLC used for operation/ protection of boilers, waste heat boilers.	ELOP II- HIMA	SIMATIC S7
9	Motor control center (MCC)	A form of PLC used for the operation/protection of electric motors	ECS Siemens, 1 PLC S7-400H 2 HMI	PCS 7 V7.1
10	Complex compressor controller (CCC)	To operate compressors and steam turbines and are usually in the same control package as PLCs	CCC	4 Woodward Peak 150 system
11	Fire and gas system (FGS)	It is a type of safety PLC that utilizes detection of fire or leakage of hazardous gas/explosive substances	Triconex	Triconex, F&G Triconex system - 2 HMI machines, 3 MIMIC machines
12	Environment continuous management system (ECMS)	A form of PLC used to detect fire or leakage of hazardous/explosive gases Environmental impact monitoring	ECMS Emerson	Rosemount X-STREAM XEFD

***Table 2.** Main communication protocols at two fertilizer plants*

No.	System	Protocol description
1	IMS	Intranet computers using ethernet. Connect the DCS system via the OPC server (OPC protocol).
2	MMS	Connecting the Bently Nevada System for data collection (ethernet).
3	APC	Intranet computers using ethernet. Connect to the DCS system via the OPC server (OPC protocol).
4	ESD	In-network control cabinets using Modbus. Connecting a DCS system using Modbus or hardwire.
5	DCS	Control cabinets using Vnet protocol (coaxial cable or RJ45). Connect to subsystems using Modbus or hardwire.
6	PRM	Connect to the DCS system via the OPC server (OPC Protocol).
7	Truck scale	Intranet computers using ethernet. Connect to the Modbus balance bridge.

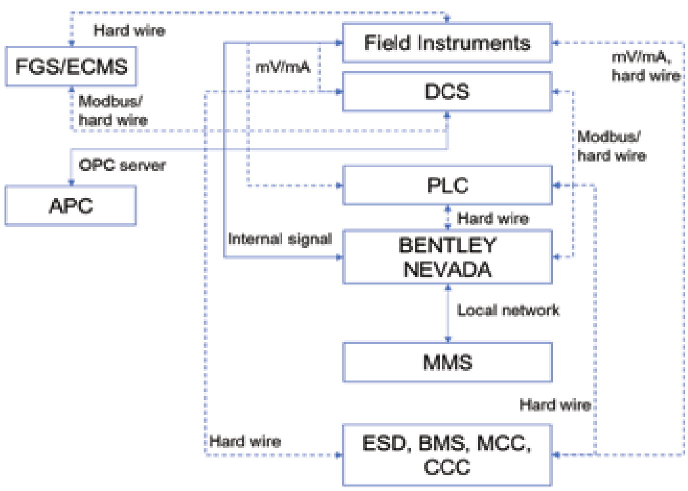

***Figure 3.** The control system connectivity at the two fertilizer plants.*

4. Digital transformation evaluation and proposal

4.1. Evaluation and proposal

At present, the plant runs with a comprehensive suite of automation control levels to manage its operations. However, this system lacks integration, optimization, and has limitations in communication, such as information connectivity between distributed control system (DCS) and utility units. Additionally, the facility has not embraced new technologies, notably wireless technology, Cloud integration, and other Industry 4.0 applications. The digitization and presentation of KPIs are contingent on the data connectivity system, extending from the process to

DCS, and the transformation of data volumes suitable for analytical applications via OPC. The operational data from the DCS of the two plants are stored in the system's historian server (HIS), as depicted in Figure 4. HIS redundantly stores data periodically and allows extraction, but the process is time-consuming and more challenging than extraction from the OPC server system. Notably, HIS does not cater to real-time data extraction.

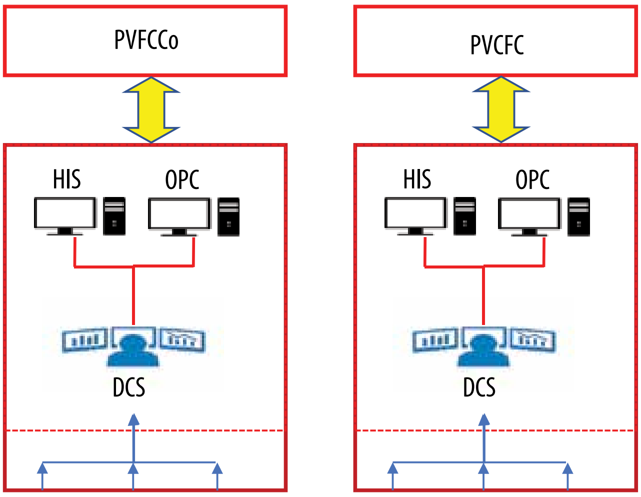

Figure 4. *The overall structure of data connection of the fertilizer plants.*

Both existing fertilizer plants have the potential to integrate new digital technology for real-time data management and retrieval. However, the most practical integration is primarily directed towards two key units, namely ammonia and urea, to oversee, optimize, and diagnose the operational processes. For other units, such as utilities, chemical management, catalysts, inventory, there are still numerous limitations stemming from the absence of meters or meters not connected to DCS, manual control, and lack of synchronous connection of the electrical system to DCS. Implementing digital technology across the entire factory will necessitate fresh investments in meter systems, management software, new servers, etc. Standardizing and centrally storing data will enable digitization and the application of data analysis technologies and machine learning throughout the plant's operations. The proposed overall connection configuration aims to display real-time information from the two fertilizer plants, synchronize data to cloud/on-premises, and provide the capability to monitor operations from Petrovietnam, as illustrated in Figure 5 [12, 13].

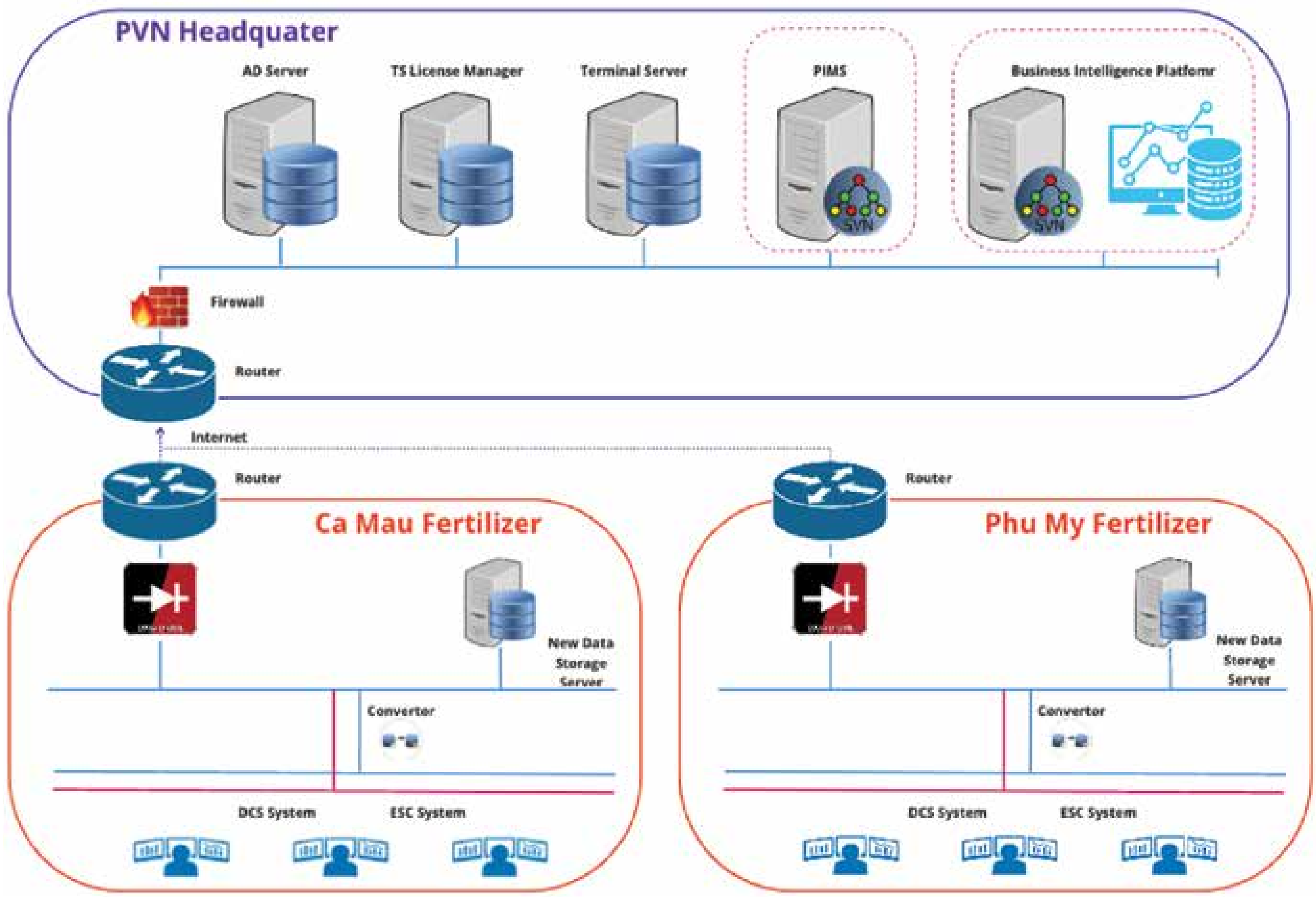

Figure 5. *Overall architectural connection plan for Petrovietnam and two fertilizer plants.*

Overall, each plant probably invests in an additional server dedicated to data storage, ensuring uninterrupted synchronization in case of transmission issues, and preparing for future factory optimization to minimize data latency. To guarantee network and data security, the system will incorporate a firewall and diode for one-way data extraction. The factory can reuse the OPC server system or PI system partially to act as a gateway and store data on a new server situated at both plants. Detailed evaluation of data transmission at the two plants is essential to meet response requirements from DCS, the number of tag names used, and the upgrade directions aligned with the OT/IT phases of the plant. Regarding the new OPC system, additional IoT devices can be seamlessly added or connected directly to the OPC. In cases where the current DCS system lacks compatibility, a direct connection to the new OPC system is feasible, thereby reducing the load on the existing DCS systems of both

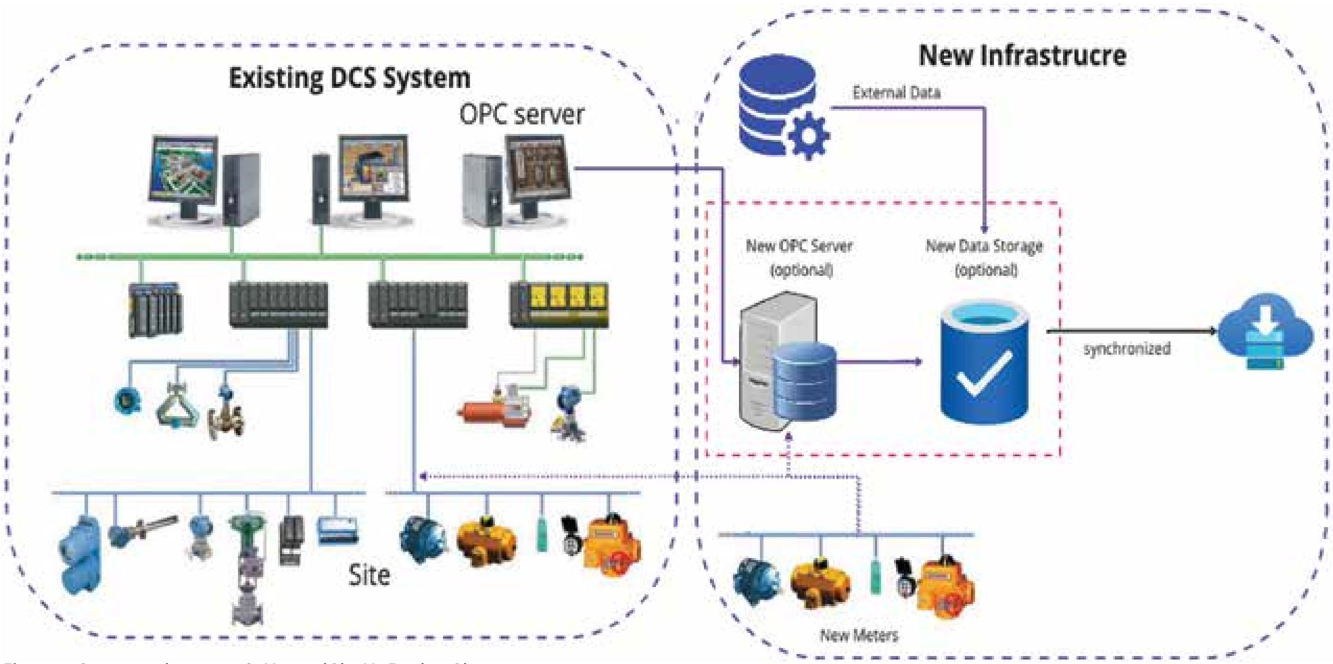

Figure 6. Connection diagram at Ca Mau and Phu My Fertilizer Plants.

Table 3. List of software/hardware and engineering service requirements for two fertilizer plants and Petrovietnam

No	Petrovietnam/Plants	Hardware	Software	Engineering & other services
1	Petrovietnam	On-premise - Active directory server - TS licenser manager - Terminal server - PIMS server on cloud (service)	1 x Exaquantum 3,000 tags 6 x User Inferface License 1 x Exaopc OPC Client 1 x OI license 1 x VPN package license 1 x software AMC (12 months) 1 x Cyber security (antivirus, firewall & data diode.	Project management in house engineering: hardware & software FAT SAT (7 days) Packing and shipping Online training (2 days).
2	Phu My Fertilizer Plant	1 x OPC server 1 x PIMS	1 x Exaquantum 3,000 tags 6 x User inferface license 1 x Exaopc OPC client 1 x OI license 1 x VPN package license 1 x Software AMC (12 months) 1 x Cyber security (antivirus, firewall & data diode).	Project management in house engineering: hardware & software FAT SAT (7 days) Packing and shipping Online training (2 days).
3	Ca Mau Fertilizer Plant (*)	In a similar manner to the Phu My Fertilizer Plant	In a similar manner to the Phu My Fertilizer Plant	In a similar manner to the Phu My Fertilizer Plant
(*): The next step involves verifying the potential for reusing the plant's infrastructure system components, including the OPC server, OSI PI, and other relevant elements.				

factories. Overview of the connection configuration at two fertilizer plants is referred to Figure 6.

With the suggested infrastructure framework above, the primary software/hardware requisites are detailed in Table 3.

With the connectivity choice mentioned earlier, future unit expansions (e.g., NPK, UFC85, etc.) can be smoothly executed by establishing data links to the existing (or supplementary) hardware system. This process involves employing similar calculation methods and algorithms, ensuring straightforward connectivity to exhibit KPIs at various levels.

4.2. Preliminary investment and economic and social benefits

The initial investment expenses and ongoing maintenance costs, outlined in Table 4, are delineated based on two alternatives: utilizing Cloud services or constructing an in-house storage server.

The benefits derived from digitization, KPI implementation, and the shift towards digital transformation in the two fertilizer production plants extend beyond improving operational efficiency and reducing production costs, such as energy and chemical consumption through KPI applications. These initiatives also result in advantages related to safety, personnel management, and supply chain optimization. More specifically, they enhance the level of management and administration at both plants and Petrovietnam, creating opportunities for sharing information and experiences across different plants and units within Petrovietnam. The overall benefits include:

(i) Direct management and supervision (economic efficiency): In addition to continuous efforts of the two

Table 4. *Total preliminary investment and annual maintenance costs*

No.	Categories	Preliminary initial costs (VND) (*)	Annual maintenance costs (VND/year)
1	Petrovietnam		
1.1	On premise	~ 21 billion	1.5 billion [0.8 (Maintenance/operation); 0.75 (software)]
1.2	On cloud	~ 19 billion	1.05 billion [0.3 billion (hire) + 0.75 billion (software)]
2	Ca Mau Fertilizer Plant	~ 9 billion	1.3 billion [0.55 billion (Operation/maintenance) + 0.75 billion (software)]
3	Phu My Fertilizer Plant	~ 9 billion	1.3 billion [0.55 billion (Operation/maintenance) + 0.75 billion (software)]
4	Total		
4.1	On-Premise	~ 39 billion	4.10 billion
IV.2	Cloud	~ 37 billion	3.65 billion
(*): The next step verifies the potential for reusing the plant's infrastructure system components (e.g. the OPC server, OSI PI, etc.) for investment optimization			

Table 5. *Benefits from similar projects*

Plant/Enterprise	Project overview	Benefits
PUPUK Indonesia	Digital transformation for ammonia/urea plants. PUPUK has implemented as planned the whole plant of PUPUK Indonesia	- 2 - 5% increase in ammonia production capacity; - 1 - 7% reduction in energy costs depending on the plant.
UOP Honeywell	Enterprise data and operations management: dashboards, reports, graphics, historian, alarms and operation monitoring	- USD 2 million/location; - Collect and report data according to standards; - Integrate data from multiple sources (data lake); - Collect aggregated data for analysis; - Increase productivity.
AVEVA	AVEVA maintenance management solution pays off for CF industrial fertilizer plant	- Improve operations and reduce costs by automating facilities operations; - Successful integration with multiple systems as well as merging intuitive dashboards and KPIs, creating an optimized business workflow; - Potential to improve revenue by up to 5%; - Reduce operating costs by up to 10%.
Yokogawa	Integrated performance management	- Profit brings USD 5 - 15 million after applying; - Reduce energy consumption: 1 - 5% depending on the factory and current energy consumption; - Increase production capacity; - Reduce labor costs related to the implementation of reports.

plants to reduce energy and chemical consumption, the application of KPIs based on actual operational data follows a scientifically validated approach used globally in fertilizer plants. This enhances the management and supervision of production operations by:

+ Measuring energy consumption and system efficiency;

+ Identifying areas for optimization and reasonable consumption reduction;

+ Optimizing operations and reducing standard consumption through continuous online monitoring using digital tools and constraint-based KPIs [5, 14, 15]. This optimization process results in reduced energy and input consumption for the plant, typically achieving energy savings ranging from 1% to 5% of the total energy consumption in the initial year of implementation based on experience from similar projects (Table 5) [16 - 19].

(ii) Indirect management and monitoring efficiency (Social efficiency)

- For Petrovietnam:

+ Adoption of a uniform online management tool using a consistent approach for both plants.

+ Implementation of digitalization through KPIs and benchmarks to elevate the level of management, enhance automation, and align with industry development trends. This contributes to strengthening Petrovietnam's brand in the realm of digital transformation and fostering sustainable development.

+ Real-time online data monitoring facilitates swift decision-making during emergencies, backed by a robust scientific foundation for approving targets in the annual plans of both plants and monitoring task execution.

- For PVFCCo/PVCFC:

+ Realization of benefits (like the Petrovietnam level), this creates a coherent chain of efforts and modern management practices.

+ Establishment of scientific benchmarks, from systems to the entire plant, provides crucial information for optimizing financial software.

+ Reduction in labor and other costs for collecting information from units, processing information from departments to execute and report to the Group's leadership.

+ Enhancement of safety, environmental protection, and process compliance, improvement in product quality.

+ Efficient operational team management and enhancement of the management/administration level.

+ Assessment of equipment and technology line performance.

+ Facilitation of experiences/information sharing and mutual learning between the two plants.

These management benefits, while challenging to quantify specifically, strategically contribute to the modern development of Petrovietnam's management for the two plants, particularly as the impact of digital transformation continues to grow in the oil and gas sector. This initiative sets the stage for Petrovietnam's comprehensive digital transformation across all its plants.

5. Conclusions

This study, partially funded by Petrovietnam, has conducted a comprehensive evaluation of the infrastructure, OT/IT systems, and data management for two fertilizer plants. Although equipped with advanced automation control technology, the plants face challenges in integration, connectivity, and inter-system communication. Recognizing the need for enhancement and integration of digital technology to improve efficiency, the study proposes a preliminary application to connect KPIs displays. The outlined project involves an initial investment of approximately VND 37 - 39 billion, with annual maintenance costs ranging from VND 3.7 - 4.1 billion.

Despite the initial high costs, the potential for significant energy and cost savings makes the digitization of the fertilizer plants economically feasible. Moreover, the project's positive impact extends beyond economic benefits, enhancing sustainability, management practices, and the overall reputation of both the fertilizer production plant and Petrovietnam within the community and the global business context. The project positions the fertilizer plants and Petrovietnam as technology leaders, contributing to sustainability and elevating their global industry standing.

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