COMSERVA: Jurnal Penelitian dan Pengabdian Masyarakat
Volume 4 No. 9 Januari 2025 (XXX-XXX)

e-ISSN: 2798-5210
p-ISSN: 2798-5652

Optimizing Energy and Electricity Manage-ment Through Technical and Economic Analysis of Automation Technology Lifecy-cle Management in Power Plants

Weldi Wanto
Universitas Indonesia, Indonesia
*Email: weldi30@gmail.com

DOI:10.59141/comserva.v4i9.2808

ABSTRAK

The rapid advancement of automation technology in power plants has created a need for com-prehensive lifecycle management analysis to ensure that technical and economic aspects are op-timized throughout the plant's operation. This study focuses on improving energy and electricity management by evaluating the lifecycle stages of automation technology, including a case study on a specific product. The technical analysis examines the compatibility of new automation technology with existing infrastructure and its scalability for future upgrades, while the econom-ic analysis considers initial capital investment, operational costs, and long-term savings from in-creased efficiency and reduced downtime. By integrating both technical and economic perspec-tives, this study offers a holistic approach to enhancing energy and electricity management. Ef-fective lifecycle management of automation technology in power plants is essential for improv-ing operational efficiency, ensuring cost-effectiveness, and supporting sustainable energy man-agement. This research contributes to a deeper understanding of the relationship between tech-nical performance and economic considerations, advancing the field of power plant automation technology and optimizing the management of automation systems throughout their lifecycle

Keywords: Lifecycle Management, Automation Technology, Energy Management.

INTRODUCTION

In the current era of industry 4.0, increasingly sophisticated technological developments produce an increasingly modern lifestyle (Haqqi & Wijayati, 2019). Behavioral changes in the era of globalization occur at many times which have an impact on the younger and older generations, especially financial behavior (Rohmanto & Susanti, 2021). There are advances in modern life around the world and advances in financial technology are one of them. Financial technology includes technological advances and the provision of financial services has evolved from more traditional forms of business to more modern forms of business, for example, although in the past business had to be done face-to-face, today the same transaction can be completed online in a matter of minutes (Erdi, 2023). Access to the financial sector has become faster, simpler, and more realistic through modernization in the fintech industry.

When viewed from the perspective of financial technology, internet loans are among the most popular among Indonesian people because they save a lot of time, and prospective borrowers also find online loans very convenient (Hasan et al., 2022). The availability of internet loans has become a controversial issue for people in Indonesia who have low financial literacy. Online loans have been the subject of several lawsuits in Indonesia, but some borrowers are looking for them Power plants are very complex infrastructures, involving various systems and components that must work synergistically. Automation technology, like Distributed Control System (DCS) is the right technology to be used in such complex infrastructures. In addition, effective automation technology can help optimize energy consumption, reduce energy waste, and increase the use of renewable energy sources. The reliability and safety of power plant operations also depend heavily on the effectiveness of automation technology. Advanced automation technology can detect and respond to problems quickly, reducing the risk of failures that can lead to downtime or even disasters. In addition to the increasing demand for energy, power plants in many countries are also regulated by various strict regulations, one of which is the pressure to reduce carbon emissions, increase energy efficiency and ensure energy sustainability. Automation technology used in power plants must be designed and managed to support the fulfillment of all these regulatory requirements.

Automation technology has seen rapid advancements in recent decades, enabling more efficient, reliable, and safe power plant operations. As new automation technologies emerge and business needs evolve, many automation customers have adopted strategies to extend the lifespan of their automation systems, which control their production processes. When well-managed, automation technology can provide increasingly better performance throughout its lifecycle, rather than deteriorating over time. With proper maintenance, this technology can be preserved in a way that significantly extends its lifespan and continually enhances its performance (Maxwell, 2024)

Automation technology is closely related to the industrial revolution 4.0, and this technology continues to develop, not only its ability to control complex industrial processes, its ability to integrate with other advanced technologies is also a must, because this ability will further increase the benefits of automation technology in the operation of more efficient, reliable and safe power plants. Power plants in Indonesia, some have been operating for more than 20 years, the Distributed Control System (DCS) as the automation technology in these power plants has certainly experienced a decline in performance, so in addition to analyzing the feasibility of the operation of these power plants, it is also necessary to conduct an analysis by considering the integration between technical and economic aspects of the lifecycle of automation technology in these power plants.

Automation system vendors typically have a life cycle indication for components or system divided into several phases, based on principles defined in IEC 62402, Obsolescence management – Application guide. To overcome these variations, this recommended practice defines a generic lifecycle model (Ferreira et al., 2023). Obsolescence does not happen on a specific date and rather is a gradual process that starts with the OEM discontinuing support. Spare parts then become harder to procure and more expensive to repair. At some point, spares become too expensive or too hard to find, and maintaining the control system becomes difficult, and the system must be replaced or upgraded. Figure 1 shows the typical life span in years of various DCS components. The life cycle of a control system can be viewed from three different perspectives that build on each other to finally govern the overall life cycle of a distributed control system (DCS). First, the technology being used in control systems has life cycles shaped by advances in networking, central processing unit (CPU), communications, and software. Second, as commercial products, control systems have their own life cycles that are influenced by technology, market trends, and competitiveness. Finally, from an end-user's perspective, the control systems in use have a limited life span influenced by failure rates, original equipment manufacturer (OEM) support, and technological trends (Taratukhin et al., 2016).

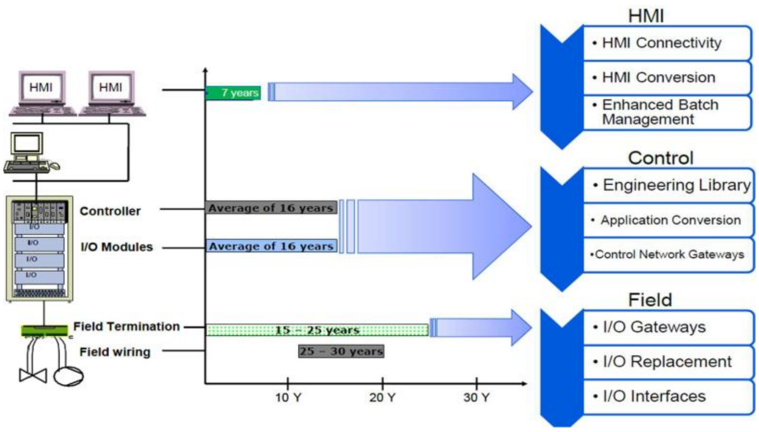

Figure 1 Typical Lifecycle of DCS components in years

For a new project or existing systems replacement/migration, life cycles should be part of the analysis when deciding to purchase a control & automation system. Technology life cycles describe the stages a technology goes through over time. In the beginning, many refer to new technology as "bleeding edge"- when it shows high potential but hasn't demonstrated its value or settled down into any kind of consensus. Examples of this include the early implementations of microprocessors, PLCs, Ethernet, Windows HMIs, and direct digital control. When everyone agrees that a particular technology is the right solution it becomes "state of the art". As the technology ages, it is referred to as "dated" – when it is still useful, still sometimes implemented, but a replacement "leading edge" technology is readily available to take its place. At some point, technology becomes "obsolete" – when it has been superseded by other state-of-the-art technology. Obsolete technology becomes significantly more expensive over time, there are less people that understand it, and at some point, it is no longer sold (Vanderroost et al., 2017).

Emerging technologies defined as "a relatively fast-growing and radically novel technology characterized by a certain degree of coherence persisting over time and with the potential to exert a considerable impact on the socio-economic domain(s) which is observed in terms of the composition of actors, institutions, and the patterns of interactions among those, along with the associated knowledge production processes (Rotolo et al., 2015). Automation technologies such as distributed system control (DCS) are closely related to the industrial revolution 4.0, and this technology continues to develop, not only its ability to control complex industrial processes, its ability to integrate with other advanced technologies is also a must, because this ability will further increase the benefits of automation technology in the operation of more efficient, reliable, and safe power plants. Power plants in Indonesia, some have been operating for more than 20 years, the automation technology in these power plants has certainly experienced a decline in performance, so in addition to analyzing the feasibility of operating the power plant itself, it is also necessary to conduct an analysis by considering the integration between the technical and economic aspects of the lifecycle of automation technology in the power plant. What kind of strategy from a technical aspect has maximum implications for increasing the efficiency, reliability, and safety of the power plant, but from an economic aspect, this strategy does not require large investments, and the implementation process does not cause long downtimes that cause other production losses.

There are four phases in an LCA study, the goal and scope definition phase, the inventory analysis phase, the impact assessment phase, and the interpretation phase (Standard, 2006).

The scope, including system boundary and level of detail, of an LCA depends on the subject and the intended use of the study. The depth and the breadth of LCA can differ considerably depending on the goal of a particular LCA. The life cycle inventory analysis phase (LCI phase) is the second phase of LCA. It is an inventory of input/output data regarding the system being studied. It involves the collection of the data necessary to meet the goals of the defined study. The life cycle impact assessment phase (LCIA) is the third phase of the LCA. The purpose of LCIA is to provide additional information to help assess a product system's LCI results to better understand their environmental significance. Life cycle interpretation is the final phase of the LCA procedure, in which the results of an LCI or an LCIA, or both, are summarized and discussed as a basis for conclusions, recommendations and decision-making in accordance with the goal and scope definition.

Challenges associated with LCAs of emerging technologies include issues related to lack of data, scale-up, a lack (in some cases) of incumbents against which to compare, and uncertainty with respect to both how the emerging technology will be deployed as well as the market conditions into which the technology will be deployed (Bergerson et al., 2020). Because both technology and energy industry are related and continue to develop, there will be uncertainty variables if we want to conduct a lifecycle assessment. Therefore, in this study, the lifecycle assessment that will be conducted is a prospective lifecycle assessment. Conducted only to automation technology in power plants, with the aim of obtaining its lifecycle management strategy. To create a prospective lifecycle assessment framework, based on the general mechanism of product lifecycle assessment ISO 14040/44, the next stage of this study is to identify input and output variables. These variables are identified based on technical and economic aspects, which are related to automation technology in power plants.

The input variables, including determining the objectives and scope of the lifecycle assessment, and identifying automation technology data from a 600 MW power plant unit, this is a technical aspect. Sample of the automation technology data structure that will be used is based on Table 1 as follows:

Area	Unit
Turbine control Base control Auto start BFP control	Total I/Os signal (Tags)
Boiler control	Total I/Os signal (Tags)
Motor control	Total I/Os signal (Tags)
SOE & data acquisition	Total I/Os signal (Tags)
Sootblower	Total I/Os signal (Tags)
Burner management	Total I/Os signal (Tags)
Interfaces	Total I/Os signal (Tags)
Operator HMIs	Total Computers
Operator graphics	Total Graphics
Engineering workstation	Total Computers
Historian interface	Total I/Os signal (Tags)

Figure 2 Plant Automation Data

The output variables will consist of the interpretation of the results of the lifecycle assessment after being analyzed from the technical and economic aspects of its impact on energy and electricity management. In addition, this output variable is also to identify lifecycle management strategies for automation technology in power plants and determine the most effective strategy in supporting energy and electricity management after considering it from the technical and economic aspects.

It has always been the ambition of power plant operators to manage their plants in the optimum way to provide the highest heat rate or a high level of flexibility to generate the highest economic returns. What modern automation systems have brought is the ability not just to optimize the elements of the power plant, piece by piece, but the ability to optimize the whole plant as a single unit. So today, when plant operators talk about power plant optimization, they are talking about this holistic view of plant control. In practice this whole-plant optimization has clear aims, and two are emerging as the most important, namely efficiency and flexibility (Neimark, 1972). In many cases, older systems from former technology generations cannot meet these requirements. State-of-the-art control systems provide more transparency and improved information for operating staff and faster elimination of disturbances.

Key requirements are higher manoeuvrability of plants regarding MW output and load changes while maintaining high efficiency levels throughout the complete load range, i.e. also being efficient in lower load conditions. Primary measures for achieving these requirements concern adaptations of the mechanical and process part (i.e. boiler, turbine and valves). Secondary measures address implementation of efficient control of the combustion process, adaptations to instrumentation and control, process information and optimization programs. Varying lifecycle periods of the many different components and systems must be managed while meeting performance targets and complying with law and regulations at the same time. The sequence of the needed improvements is dependent on the life cycle of the questioned component on the one hand side and on the other side on changes requested from the operation (Turconi et al., 2013). Regarding to a distributed control system for thermal power plants (which are the main source of a stable electricity supply), after its equipment has been running for a dozen years or so, the need for lifecycle assessment, from the viewpoint of preventative maintenance, becomes more urgent. When it comes to such equipment upgrading, the most important point is to complete the work during the predetermined inspection period. Moreover, to lighten the workload on operators, enlarging the automated range and improving monitorability and operability at the same time are being strongly demanded (Shimizu et al., 2006).

Technology plays an important role in energy management by providing various solutions and innovations to improve energy efficiency and security. Various technology approaches in energy management include smart grids, energy monitoring, Internet of Things (IoT), continuous energy connectivity, electricity management software, energy solutions, electrical solutions (Nasab et al., 2024). And automation technology like distributed control system, through its technology lifecycle management, ensuring the new technology integration is possible, and that integration work can be done during the predetermined inspection period of the power generation plant.

METHOD

The methodology of this research is carried out by implementing the general mechanism of ISO 14040/44 product lifecycle assessment, which is then detailed into a prospective lifecycle assessment. The lifecycle management of automation technology will be analyzed by first collecting several data variables, related to the application of automation technology in power plants and its implications for improving energy and electricity management. Figure 2 below shows the flow chart of this research.

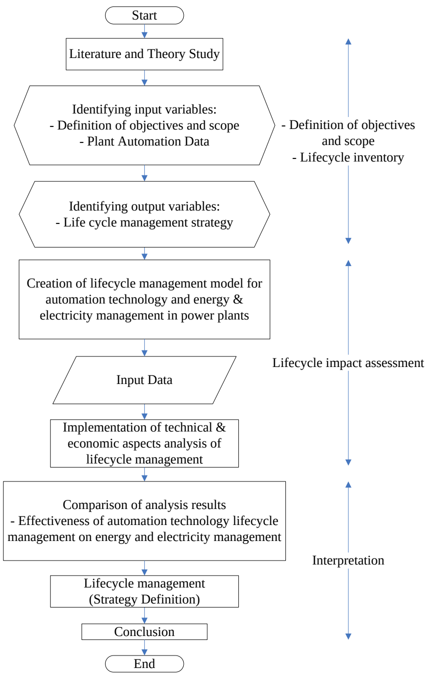

Figure 3 Research Flow Chart

Qualitative methodology is used to explain these data variables, then these data variables are analyzed so that the relationship and comparison can be seen, between energy management and lifecycle management of automation technology in power plants. Then with quantitative methodology, more specific data, in the form of numbers, are used to analyze the technical and economic aspects of the automation technology lifecycle management. The technical aspect focuses on the analysis of technical data about the performance and lifecycle management of automation technology, to determine the level of effectiveness in achieving system efficiency, maintaining system reliability, and reducing system downtime. Economic aspects, focusing on the analysis of economic data on costs incurred due to system downtime, decreased system efficiency due to automation technology failure, then cost-benefit analysis of automation technology maintenance, and its lifecycle management.

Based on the existing plant automation data and the lifecycle status of the installed distributed control system, as indicated by OEM data, this research methodology defines several midpoints and an endpoint for our lifecycle impact assessment. Each midpoint contributes to the endpoint, which represents the goals and objectives of the lifecycle management strategy aimed at optimizing energy and electricity management in the power generation plant. The following factors are considered as the midpoints for this lifecycle assessment: Operation and Maintenance Costs of the Control System, Control System Reliability, and the Costs Associated with Unit Trips and Downtime.

POWER GENERATION PLANT AUTOMATION ASSET OPERATION AND MAINTENANCE	Unit
Number of power generation plant asset (IO based) to be managed by automation system	analog & digital
Number of power generation plant asset (HMI) to be managed by automation system	computers
Average number of minutes to perform automation maintenance per asset per year	minutes/year
Average number of minutes to perform automation problem troubleshooting per asset per year	minutes/fault
Average number of minutes to replace & re-engineering automation component per occurance of failure	minutes/fault
Hourly maintenance burden cost rate	cost/hour

Figure 4 Operations and Maintenance Cost Estimation of The Control System

For the control system reliability, we are calculating this based on the OEM data, for each of the automation component related to some standard product reliability measurement.

$$MTBF = \frac{1}{\lambda} \quad (1)$$

Where:
MTBF = mean time between failures in hours
λ = failure rate per hour

$$MTBT = \frac{MTTF}{Installed\ Count \times Trip\ Probability} \quad (2)$$

Where:
MTBT = mean time in hours between unit trips caused by a specific control system failure
MTTF = mean time to failure of the specific control system component
Installed count = number of the specific component installed
Trip probability = probability that a single failure will cause a unit trip

$$Trips\ per\ Year = \frac{24 \times 365}{MTBT} \quad (3)$$

While to determine the last midpoints, which is cost impact associated with unit trip and downtime, this will be based on the total cost of operating margin loss per hour of forced outage because of control system failure adding with the startup cost.

RESULT AND DISCUSSION

Lifecycle Management Goal and Objective Definition

The goal and objective of the lifecycle management is to ensure the sustainable achievement of optimal performance in the electrical system, energy efficiency, and cost-effectiveness throughout the lifecycle of automation technology installed in the power generation plant. To achieve that goal, we need to enhance the performance of automation technology over its lifecycle by identifying the most effective lifecycle strategy, determined through technical and economic analysis.

The Distributed Control System Lifecycle Inventory Analysis

The 600 MW coal fired power generation plant used a distributed control system. Figure 3 shows the distributed control system architecture, and Figure 4 shows the overview of the distributed control system technology. From the literature study and collected data, the automation technology used by the power plant has been introduced by its manufacturer to the industry since 1980.

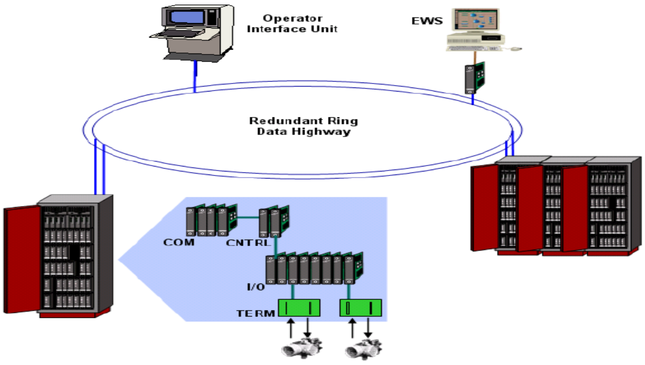

Figure 5 The Distributed Control System Architecture
Source : (Porfilio & Generation, 2008)

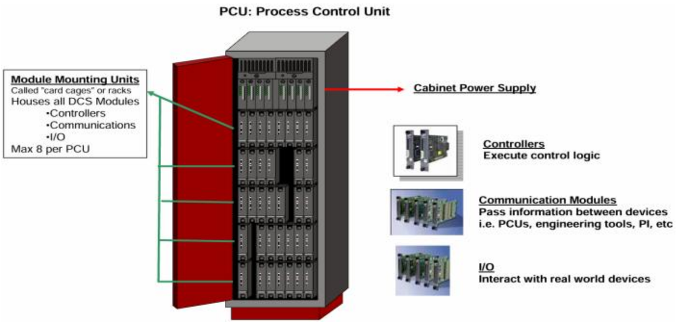

Figure 6 The Distributed Control System PCU Overview
Source : (Porfilio & Generation, 2008)

In this research, referring to Figure 1, the lifecycle assessment will exclude field termination and field wiring. The installed distributed control system inventory analysis in the 600 MW coal fired power generation plant can be found in Table 2 below as the plant automation data. The installed distributed control system has in total 29 process control units (PCU), with detail on the input output signals as shown in Table 3.

Area	Control Unit & Type		I/O
	Control Unit	Type	
Boiler, Turbine & Generator(Operation & Control)			Total I/Os signal (Tags)
	PCU 1 PCU 2 PCU 3 PCU 4 PCU 6 PCU 11 PCU 12 PCU 16 PCU 19 PCU 20 PCU 21 PCU 22 PCU 23 PCU 26 PCU 31 PCU 34 PCU 35 PCU 37 PCU 38	MFP02 AMM03	5118
Sootblower			Total I/Os signal (Tags)
	PCU 5	MFP02	737
Burner management			Total I/Os signal (Tags)
	PCU 27 PCU 28 PCU 29	MFP02	929
Interfaces			Total I/Os signal (Tags)
M/T DEHC LINK BFPT DEHC LINK BFPT TSI LINK M/T TSI LINK ELECTRICAL PRECIPITATORS CEM	PCU 46 PCU 47 PCU 48 PCU 49 PCU 50 PCU 51	MFP02	808
Operator HMIs			Total Computers
			8
Operator graphics			Total Process Graphics, Reports & Trends
			866
Engineering workstation			Total Computers
			2
Historian interface			Total I/Os signal (Tags)
			7000

Figure 7 The 600MW Power Generation Plant Automation Data

Based on the literature review, this research also considers the lifecycle plan of the automation technology provided by the product's OEM. Table 4 outlines the lifecycle plan for each component of the distributed control system installed in the 600 MW power generation plant, as per the automation data previously collected from the plant. Meanwhile, Figure 5 illustrates the evolution of the OEM's product in terms of both software and hardware technologies. This data will be used to analyze the technical aspects, as automation technology continues to emerge and evolve.

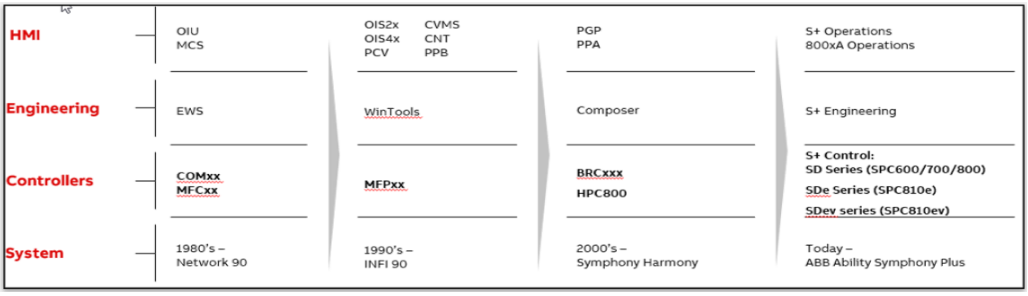

Figure 8 The OEM Distributed Control System Product Technology Evolve [14]

Contact Information:		**System size:**	
Customer Name:	600MW Coal Fired Power Plant	Number of I/O:	5,001 - 10,000
Site:	0	Number of Tags:	10,001 - 20,000
Location:	Indonesia	# of Operator Stations:	6
Industry:	Power Generation	# of Engineering Stations:	1

Installed system description:		**Lifecycle Status**	**Support Status**
Controller type:	INFI 90 Open / INFI 90 Controllers (MFP)	Obsolete	Evolution Recommended
Controller type:	Network 90 Controllers (MFC, AMM, LMM, COM)	Obsolete	Evolution Recommended
I/O type:	Harmony / INFI90 Open / INFI 90 I/O (IMxxxxx)	Limited	Evolution Recommended
System Communications:	INFI-Net - Harmony / INFI 90 Open / INFI 90 (INxxxxx)	Limited	Evolution Recommended
Cabinet Power Supplies:	Modular Power System III (MPS III)	Limited	Evolution Recommended
Engineering Tools:	Composer	Obsolete	Evolution Recommended
Operator Workstations:	OIS 20 Series (includes OIS 20 and OIS 25)	Obsolete	Evolution Recommended

Figure 9 The OEM Distributed Control System Product Lifecycle Status

The Distributed Control System Lifecycle Impact Analysis

As per the goal and objective definition, the lifecycle impact analysis in this research for the distributed control system is on its technology. The prospective analysis on the installed technology and its emerging to enhance the performance of the distributed control system, to achieve sustainability and the optimal performance of the 600 MW coal fired power generation plant. The automation technology data collected from the power generation plant, and shown using the three midpoints of lifecycle impact analysis, as below:

Operation and Maintenance Cost of a Control System

Using the total assessed analog and digital I/O, we developed Table 5 and Table 6 below to outline the annual operation and maintenance costs that the power generation plant operator will need to incur for the current installed automation technology which already in operation for 20 years. These costs are projected to increase by 3% per year, assuming continued maintenance of the existing distributed control system technology.

POWER GENERATION PLANT AUTOMATION ASSET OPERATION AND MAINTENANCE		
Number of power generation plant asset (Module IO based) to be managed by automation system	7,592	analog & digital
Number of power generation plant asset (HMI) to be managed by automation system	10	computers
Average number of minutes to perform automation maintenance per IO based asset per year	10	minutes/year
Average number of minutes to perform automation maintenance per HMI asset per year	10	minutes/year
Average number of minutes to perform automation problem troubleshooting per IO based asset per year	10	minutes/year
Average number of minutes to perform automation problem troubleshooting per HMI asset per year	15	minutes/year
Average number of minutes to replace & re-engineering automation IO based component per occurance of failure	30	minutes/year
Average number of minutes to replace & re-engineering automation HMI component per occurance of failure	120	minutes/year
Hourly maintenance burden cost rate	USD 60	cost/hour

Figure 10 Operation and Maintenance Estimated Time

Result Calculations			
Maintenance hours spent per month on plant automation asset maintenance and documentation	105.58	USD 76,020	cost/year
Maintenance hours spent per month on plant automation asset troubleshooting and documentation	105.65	USD 76,070	cost/year
Maintenance hours spent per month on plant automation asset replacement, re-engineering and documentation	318.00	USD 228,960	cost/year

Figure 11 Operation and Maintenance Estimated Cost

Control System Reliability

To develop lifecycle impact analysis on control system reliability, we assessed each of the automation technology assets and product reliability data from the OEM of the automation technology. Using formula equation (1), (2) and (3), we get below table of control system reliability, were with current product automation technology, after in operation for 20 years, the result shows in Table 7, the potential trip per-year for each of the distributed control system asset.

Module	Installed Count (IO Modules)	MTBF (hr)	MTTF (hr)	Trip Probability	MTBT (hr)	Trips per Year
Controller (redundant)	29	303.030	303.022	60.00%	17.415	0.50
Power supply (redundant)	29	714.286	714.278	60.00%	41.050	0.21
Analog output	21	163.934	163.910	30.00%	26.018	0.34
Digital output relay 230VAC	117	285.714	285.690	30.00%	8.139	1.08
Analog input	80	185.185	185.161	30.00%	7.715	1.14
TC, RTD input	107	169.492	169.468	25.00%	6.335	1.38
Digital input 24VDC	253	158.730	158.706	30.00%	2.091	4.19
Digital input pulse 24VDC	1	158.730	158.706	30.00%	529.021	0.02
Network interface (redundant)	60	222.222	222.214	60.00%	6.173	1.42
Total trips per year						**10.27**

Figure 12 Trip Risk Assessment Associated to Control System Asset Failure

Cost of a Unit Trip and Downtime

Unit trip and downtime will cause loss of revenue. With assumption price of electricity from this 600 MW power generation plant is $0,07 per kWh, and the plant is having downtime for 4 hours, it would be $168,000 loss of revenue.

The Distributed Control System Lifecycle Interpretation Analysis on Technical and Economic Aspects

Based on the results of the lifecycle impact analysis, it is evident that the reliability of the control system significantly affects the energy and electricity management of the 600 MW power generation plant. The control system, which has been in operation for 20 years, technically is experiencing a decline in reliability, as shown in Table 7, as the result, the power plant has potentially 10 trips per year because of single failure of its control system asset.

The control system reliability, besides its affected overall power plant performance, it also influences the plant's operational and maintenance costs. Additionally, OEM support has become increasingly limited, consequently, this situation ultimately leads to higher operational and maintenance costs for the power generation plant. From the distributed control system product assessment, and as per the OEM product technology status also its technology evolution, we can have now the combination and comparison of lifecycle analysis from the economic aspect, using the operation and maintenance cost of the power plant automation asset, and using the investment cost if we use OEM technology evolution, for example if we do an innovative investment on the power plant human machine interface (HMI). Using OEM tool, Table 8, we can get to know potential saving from doing the innovative investment for the power plant HMI, then we can use this into our Internal Rate of return analysis (IRR) using Excel, as shown in figure 13 below.

HMI S+ Operation - Operational Saving	
Direct savings in day to day operations	**$151,200**
Reduced plant trips and process upsets	**$76,200**
Invest the savings in other areas of your plant(Return on equity)	**3.50%**
Total overall savings in first year of operation	**$227,400**

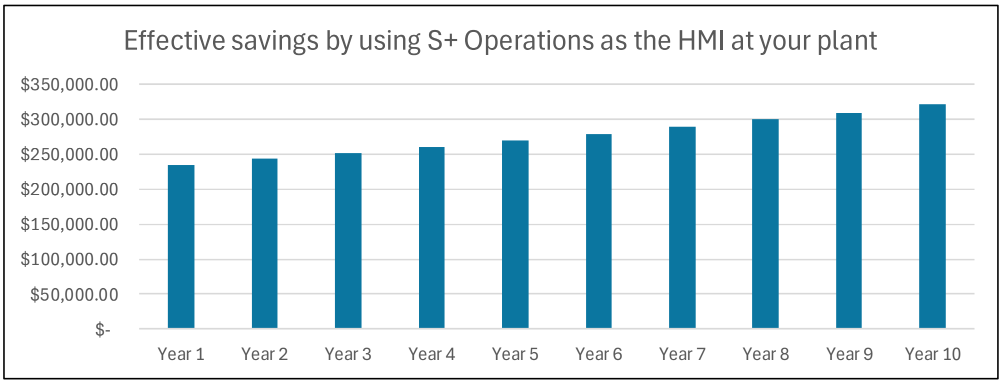

Figure 14 The Estimated Cost Saving for Innovative Investment on The Power Plant HMI

IRR of upgrading the HMI DCS and reaping benefits versus maintaining the old system					
End ofYear	Maintain (M)	Upgrade (U)	Benefits (B) of Upgrade	U+B−M	
Start				-USD 600,000	
1	-USD 381,050	-USD 600,000	USD 227,400	USD 8,450	
2	-USD 392,482	USD 380,707	USD 227,400	USD 1,000,589	
3	-USD 404,256	USD 392,128	USD 227,400	USD 1,023,784	
4	-USD 416,384	USD 403,892	USD 227,400	USD 1,047,676	
5	-USD 428,875	USD 416,009	USD 227,400	USD 1,072,284	
6	-USD 441,741	-USD 403,529	USD 227,400	USD 265,613	
7	-USD 454,994	-USD 415,634	USD 227,400	USD 266,759	
8	-USD 468,643	-USD 428,104	USD 227,400	USD 267,940	
9	-USD 482,703	-USD 440,947	USD 227,400	USD 269,156	
10	-USD 497,184	-USD 454,175	USD 227,400	USD 270,409	
				IRR	
				5 yrs	85%
				10 yrs	86%

Figure 15 IRR Analysis After Implemented Innovative Investment on the HMI

Based on the research analysis, the evolution or upgrade of automation technology, including partial upgrades, for example, in this research the HMI upgrade as the innovative investment is implemented, it demonstrates how this innovative investment can significantly enhance the performance of a power plant with a 20-year-old control system. The upgrade improves the daily operations of plant operators, providing a fully integrated solution with robust alarm management. This helps prevent production losses caused by spurious trips, process disruptions, and unplanned shutdowns.

CONCLUSION

Power generation plant owner often address the lifecycle of the automation technology only when OEM support ends, or when the automation technology asset shown decrease of its relia-bility, mean trip per year because the failure of single automation asset the probability increase. This is considered late and impacts the power generation plant performance to ensure sustaina-ble and reliable energy production. Optimizing energy and electricity management in power plants involves implementing strategies and technologies. OEM provides automation product lifecycle planning, so power plant owners can do services to audit or assess the installed auto-mation technology and align the audit or assessment report with business objective. Implement-ing strategies is on the approach taken finally to manage the entire lifecycle of the automation technology and based on the analysis the strategy which deliver maximum value throughout lifecycle, at the same time also minimizing operation and maintenance cost, risks and environ-mental impact is upgrade strategy. While on the implementation of technology, the technical as-pect analysis shows the automation technology evolution through upgrade strategy improved reliability, efficiency in operation, and compatibility with advanced and latest standards.

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