White Paper

Driving reliability, efficiency and safety on LNG/LPG vessels through automation

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KHØ

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Table of Contents

1 Document Introduction

1.1.1 Abbreviations

All abbreviations referred in this document are found underneath in Table 2

Table 1 - Abbreviations

Abbreviation	Description
CTS	Custody Transfer System
DP	Dynamic Positioning
FDS	Functional Design Specification
FO	Fuel Oil
GCU	Gas Combustion Unit
GVU	Gas Valve Unit
HAT	Harbour Acceptance Test
HMI	Human Machine Interface
HSE	Health, Safety and Environment
Høglund	Høglund Marine Solutions AS
HW	Hardware
I/O	Input/Output Signal
IAS	Integrated Automation and Control System
LNG	Liquid Natural Gas
LPG	Liquid Petroleum Gas
LTS	Long Time Support
MG	Main Generator
MSB	Main Switch Board
MTBF	Mean Time Between Failure
MTTR	Mean Time to Repair
OPC	OLE for Process Control
OS	Operator Station
PLC	Programmable Logic Controller
PMS	Power Management System
PSV	Platform Supply Vessel
SAT	Sea Acceptance Test
SW	Software
TCO	Total Cost of Ownership

1.2 Health, Safety and Environment

Høglund puts the physical and mental health of employees, customers and all other people involved first. All work is carried out in a safe manner to protect our employees, customers and the environment. Høglund sets high standards for the environment and takes responsibility for ensuring that products and services are delivered in an environmentally friendly manner.

1.3 Laws and Property

1.3.1 Laws and Regulations

Høglund Marine Solutions AS is a privately held company regulated by applicable Norwegian laws and regulations valid for all companies, such as laws for tax and reporting, shareholder registrations, work environment, vacation law, internal control regulations, HSE-regulations and all others relevant for the type of business we are in. Compliance to these laws are non-negotiable.

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2 Introduction

As the popularity of LNG as a marine fuel grows, the LNG carrier segment continues to expand, while a new generation of vessels is emerging to meet the growing demand for LNG bunkering services. Høglund is pioneering the automation of these vessels and has fitted a number of LNG-powered ships with its automation solutions. While automation system interfaces and design have evolved to fit big scale LNG carriers over the last four decades, medium and small-scale LNG carriers/bunker vessels is a new market, which is still not optimized. This opens up the opportunity for new ideas and fresh thinking to ensure success in the automation of these new vessel types. But as always with new technologies, reliability, efficiency, and safety must be prioritized to make sure systems are working as intended, while still reducing capex and opex.

Modern Integrated Automation System (IAS) on board LNG/LPG vessels consists of thousands of input and output signals with widespread signal interfaces and functions. The IAS is wired together to solve many tasks, which alone can be trivial, but put together become complex. Høglund has always focused on splitting up complicated tasks and implementing them as series of easy tasks - an approach, which has a track record of success in all our projects. We structure the complete project in lists where all similar functions are organized together. This gives a good overview of the complete process and breaks down the tasks, which enable more powerful development.

2.1 New Business

When new business segments are developed, it is important that all participants are responsive to what can be inherited from other segments and which components must be replaced or reengineered to fit the new segment. Høglund has extensive experience from several fields within marine automation: oil rigs, passenger ships, chemical tanker, ferries as well as advanced offshore construction and seismic vessels. This background makes Høglund a competitive player in the new small-scale LNG segment, which is rapidly growing at present time. This paper will discuss methods of designing marine automation systems with response to overall philosophy, segmentation, equipment under control, signal flow, logging and data distribution while ensuring total cost of ownership is kept low.

2.2 Primary Design Consideration

When designing a commercial vessel, automation is often not considered in detail by the design company responsible for the basic ship design. However, the technical specifications ship owners use against shipyards to get a tender on a vessel are often partly written by the design company. Because time is a critical component, many of the more general aspects of a ship are just copied from previous specifications. Examples of this practice can be cabin facilities for crew, or even the automation system. The result is that the shipyards, which are also competing against each other, will quote a ship per specification, with the cheapest possible automation system.

2.3 IAS Design Philosophies

In the current market, there are two prevailing design philosophies. These philosophies are both focusing on getting the lowest possible cost of a complete IAS system while maintaining reliability, safety, and efficiency of the vessel. The main difference is the means each philosophy uses to achieve its goals. The industry is under constant cost pressure to deliver cheaper and more reliable ships.

2.3.1 Segmented Approach

To avoid headaches during commissioning, many of the systems are delivered as “turn key” systems where a pump manufacturer or a valve manufacturer delivers their own proprietary control system. A serial line will then provide the link to the Integrated Automation System. This way of designing a system has its advantages – such as segmented commissioning responsibilities between the IAS and valve supplier, which can run in parallel, leaving only the interface between the two to be tested before the whole plant is complete. Splitting up the various systems allows for competition between the subcontractors of the yard. The shipyard can easily manage the risk since changing out a system even during construction will be possible, although undesirable.

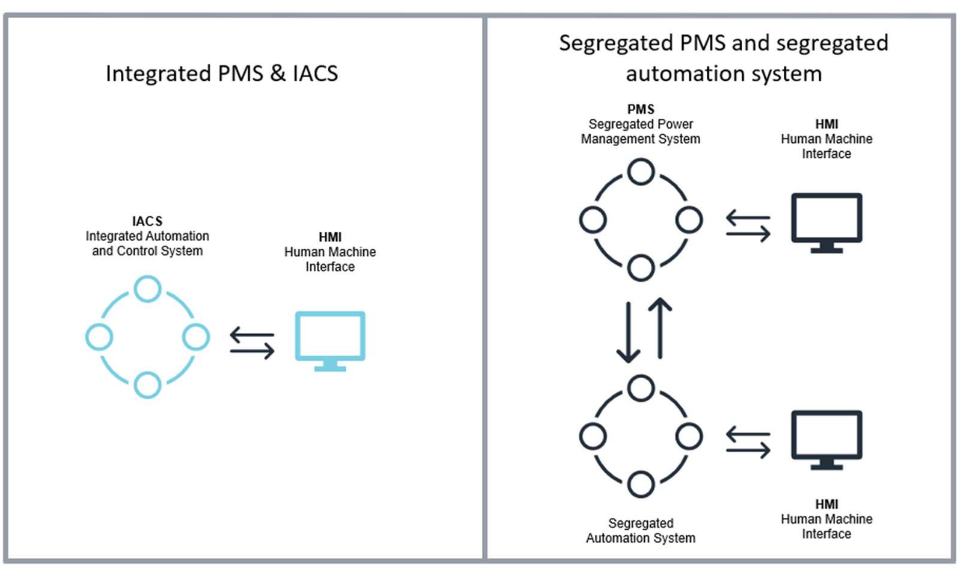
2.3.2 Integrated Approach

Another approach will be for the shipyard to organize all automation functions and specify them for the chosen IAS supplier to implement them, so that the IAS supplier is only delivering I/O modules, CPUs, and HMI. Sensors and actuators can then be purchased from other vendors, which specialize on their domains and therefore are delivering equipment both cheaper and with higher quality than suppliers that try to focus on everything. Signal interfaces between sensors and IAS need to be standard for this approach to work and this makes competition between IAS suppliers more intense since there are many competitors utilizing standard industrial HW.

Control functions are realized directly in the IAS, which makes for easier debugging and modifications if parts of the system under-perform during HAT or SAT tests. Less change management cost makes systems customized to their use cheaper.

The disadvantage with this approach is that the shipyard needs to develop detailed FDS of the different control functions, which is more labour intensive than buying a standard control package for a specific system.

We have now given a very brief explanation of IAS design philosophies. Both are well applied within the marine industry. We will now go into more detail to discuss design philosophy choices when applying automation to new business segments, like small-scale LNG carriers or ships using LNG as fuel.



3 Today's situation

3.1 Increased computer utilization

Many consider the shipping industry to be conservative. This also applies to automation. Concepts widely applied throughout the industry have been inherited from the days when hardware logic and relays were controlling the plant. The industry sticks to these ideas. The reason is that they are easy and cheap to repair and on board competency to troubleshoot and to solve issues are readily available.

When a ship is sailing, the available troubleshooting and repair capabilities are what you have on board. The crew must therefore have the necessary training and tools together with spare parts to be able to fix problems hands on.

As PLCs became cheaper than conventional relays, and cost of engineering and commissioning was reduced by increased utilization of PLCs, more suppliers are installing a PLC in their systems. But it has its challenges:

Ship owners report the following issues:

- Huge increase in unexplained events from various sub-systems, sometimes with serious damage.
- Undocumented PLCs are "found" inside faulty systems for which service is hard to get.
- Faulty PLCs can put modern vessels out of operation for longer periods of time.
- The number of "sub control systems" are increasing and creating huge challenges.
- Difficult or impossible to recreate problems and find bugs.
- The crew is searching blindly in the system for the cause of an event, and desperately looking for some reason and actions to report.
- Systems need a long and troubling commissioning period, before they are performing to a minimum standard.
- The crew now often accepts poor systems if they can get around the problem.
- The occurrence of critical side effects after a SW upgrade has become common; therefore, systems with poor performance and known bugs are accepted if work-arounds are possible.
- Nobody has the full knowledge of a modern computer system.
- System upgrade has become a challenge, and sometimes a nightmare.
- Replacement of computer parts from stock has become almost impossible.

It's clear from these reports that serious issues exist. Why are the on board crew unable to correctly troubleshoot and repair the plant? Are they unwilling? Or is their training insufficient?

3.2 Documentation

3.2.1 Hardwired Connections

All wires and cables connected on board a ship are normally well documented. Cables are numbered according to which system they are a part of and interface connections are documented either in a list or by a drawing. This documentation facilitates a way to troubleshoot a plant in an easy and convenient way using a multi-meter as the main tool. Most faults can then be addressed and corrected by using the tools available to any electrician. There is a consensus about the need to have updated drawings showing actual connections.

3.2.2 Software Connection and Logic

While there is a broad consensus about the need to have documentation and diagrams in HW systems, no real effort has been put to get access to actual program running in PLC's on board ships. Ideally, the information technicians had before though the wiring diagrams should have been available on board either as printouts or online troubleshooting capabilities of the running systems. Providing information gives the crew a real possibility of finding out what's happening and to figure out the best remedy. So why is the information that crew on board need not available to them? The answer is in many cases unclear, but here are a few reasons why.

One potential reason may be that it is necessary for a particular cable, laptop, or a piece of software to be used to access the systems in question and in some cases, there is no way to protect the system against changes if access is granted. This makes the suppliers reluctant to facilitate any online mechanism for on-site troubleshooting since incorrect changing of parameters can cause serious damage to the plant and costly warranty claims.

There are also suppliers that have a service philosophy, which aims to get a certain per cent of their total revenues from service jobs and since ship-owners need to pay for service after the warranty period, on board service becomes a valuable revenue stream.

It is also a question of protecting the intellectual properties of the software making it hard to copy and read since software piracy is becoming a major concern in shipboard automation.

The advantages of installing a small PLC in a local valve controller, for instance will be eaten away if the functions of such a system will be as good as an IAS system where all the troubleshooting tools normally is embedded in the system. As proper online debugging tools are costly to develop and deliver with the system, these are often omitted.

3.3 Segmented Approach

3.3.1 Definition

We define a segmented architecture, to be several types of PLCs controlling their own equipment under control in the plant, and where signals are sent to the IAS via a communication line. SW can be standardized by the component supplier, but not always.

3.3.2 Benefits

There are obvious benefits from letting each component supplier control his own component.

First, it is the definitively the cheapest method with respect to purchase and installation, as this control system is already developed and many deliveries have been done. This means that it most likely has proved to work, and it should not raise any problems during commissioning.

Often the control system comes ready mounted and wired to the components, and this saves the yard for many concerns:

- No I/O list to be made by the yard
- No I/O checks to be performed
- Function test may be done before delivery, and the yard will save time and efforts
- The component supplier will develop tailored SW based on detailed knowledge of the product

It is also possible to claim that failures of the actual system are easier to determine, as the interface is clear due to defined signal transmissions to the superior IAS system.

3.3.3 Disadvantages

As the Software tradition within shipping is still "young", there is no established way for the owner or yard to verify that the supplied component, with its "standard" control system is working, as it should in all situations.

As a component supplier is often relatively inexperienced in SW development, there are a lot of bugs in the SW, while revision history and change management procedures are often lacking. The statistics show that a considerable part of the problems during commissioning are related to SW problems. That is not to say that this only occurs in the small independent PLC´s delivered by subsystem vendors - but that superior IAS systems are often more open to debug and tools for programming are available from the HMI.

3.3.4 SW Modification and Debugging

As the SW is stored in a proprietary PLC, and the source code for the unit is not available, it is not possible for any other representative but the component supplier to do SW modifications or parameter adjustments.

This is often a major problem, as it will require the engineer for the component supplier to be present to correct small parameter adjustments or SW adjustments due to interface differences from the standard delivery.

If a serious problem occurs during operation, it is normally not possible for the on board electrician or engineer to go into the system and make a temporary modification to proceed with operation.

It might be that an interlock signal is failing, but the actual blocking is confirmed as OK, and the crew need to proceed with the operation, but a blocking cannot be done from the superior IAS system, and only by a service engineer that will need days to attend the vessel.

If this had been done in the IAS, it probably could have been done by the crew with a standard function, or via a remote connection by the IAS supplier.

3.3.5 SW Verification and version control

Unfortunately, many smaller suppliers of PLC programs do not have the necessary skills and experience with advanced computer systems.

Most people think that a thorough SW test will ensure safe operation, but that is unfortunately not true.

A SW test does not reveal all the possible bugs in the SW, it only demonstrates that it did work during the actual test. As there are almost infinite combinations in the SW it is impossible to trust a simple test.

And unfortunately, there are no formal requirements for a PLC SW programmer, like there are for a welder or an electrician.

In addition to this, the SW programmer’s job cannot be overseen effectively, as nobody today is inspecting the SW.

Another problem is the version control. Often there is no information on this available on board the vessel, and any new versions may have been loaded after sea trial. The new SW should have been tested and checked as to previously entered parameters, and possible new functions that were implemented during harbour and sea trials, this is not always done.

4 Integrated Approach

4.1 Definition

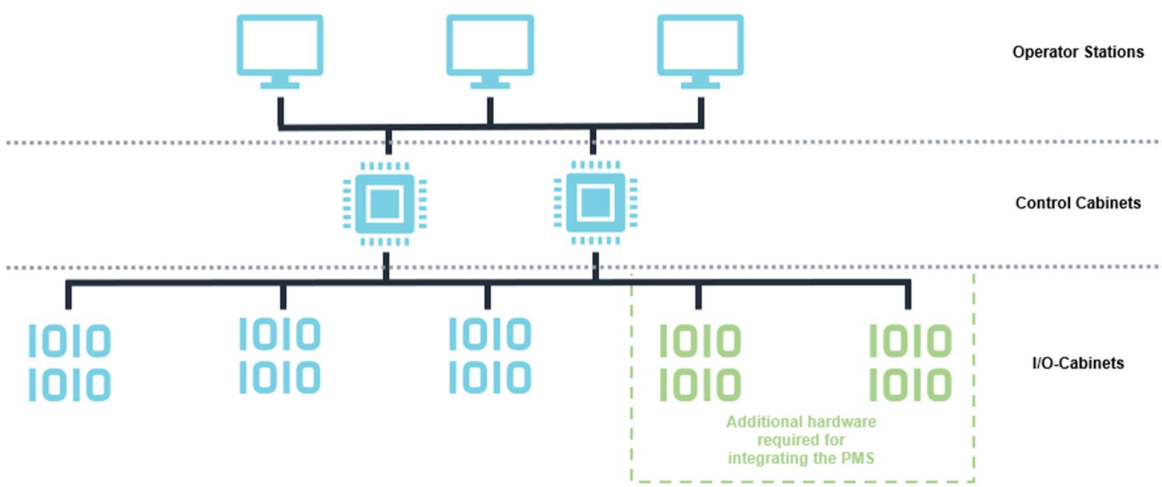
Generally, the word “full integration” can be used, when;

The same system controls the actual part of process, with the same components, the same SW modules and controlled from the same HMI, with the same operational functions as the overall IAS.

There are some questions that can be raised to find the degree of integration of a system:

- Does the system communicate with the same communication protocol?
- Are the components of the same brand, and model? I.E. uses the same spare parts?
- Does it have the same SW architecture?
- Does it use the same SW tools for programming?
- Does it use a common SW library for the programming?
- Are all properties in the database available from the IAS HMI?
- Is it possible to set ALL parameters in the system from the IAS HMI?
- Is it possible to bring up the different SW blocks in the system from the HMI for debugging?

Even if not all this is true, the system may have a certain degree of integration, but it is not done to a full extent.



4.2 Benefits

There are many benefits to selecting an integrated system:

- One single company is responsible
- Single point of contact
- Same HW
- Same HMI
- Same spare parts
- Same training courses
- Detailed I/O information in screen (as all is in the main system)
- Easy logging (as all data is in the main system)
- All parameters are stored in a central database
- One single person can debug all the way down to I/O level

4.3 Standard Hardware

Historically, it was advantageous to develop specialized hardware to control the processes on board a ship. The reason for this was, in part, that there were special requirements for signal interfaces against process and that the processes to be controlled on board a ship were of a simpler nature than that which was to be controlled in a factory shore-side. At the same time, the requirements for operational safety of a ship have been very strict as one cannot stop the process and go home if something stops working. A ship is like an island, where everything from power supply to food production and propulsion systems must be in operation to ensure ship, cargo and crew are safe. In addition, the ship must do the task for which customers have paid.

As the maritime industry is constantly hunting to find cheaper ways to acquire ships that meet both regulatory requirements as well as customer and classification societies, it opened an opportunity for companies that created proprietary control systems, specially designed for marine use.

As industrial suppliers of PLC systems noticed the potential to expand into the marine market, they went through the process of approving their products for use on board ships. This development revealed the fact that systems used shore side could be installed on ships using the same hardware and software platform, which in turn increased the quality and reduced the cost of the automation system. The only downside was that flexibility went down as one had to deal with the signal interfaces used in the industry, but this downside was very well compensated as shore-based industry control system requirements are very strict and reliability is paramount to a well-functioning factory.

4.4 Standard Software

To reduce the likelihood of errors and to further develop software, it is a great advantage to use standard software to control standard processes. Dividing up software packages induces the need for interfaces between software components, which can be painful, but defining clear interfaces is also a factor which in practice gives better control of the software and increases portability.

4.5 Challenges with Integrated Systems

An increasing number of components comes with a control system made by the component supplier. As each supplier selects his own system platform, it is not that easy for a yard/owner to get the same system all over the vessel.

To achieve commonality, each component supplier must remove the standard control system before delivery. Then the selected main system integrator must implement new control algorithms based upon the component supplier's specification. The component supplier often rejects doing this, based upon the fact that he does not trust the system integrator the task of protecting his components, and the customer will have to accept limited warranty on the package.

The result of this is that the cost of the integration rises to an impossible level, the same time as the benefits from doing this integration is very unclear for most owners.

Consequently, there is an increased segmentation of system controls, as more component suppliers are supplying their own control system. The "Integrated System" is made up of numerous communication lines to the main IAS.

Another problem is the fact that no system integrator can hold the detailed knowledge of every component or processes on the vessel. This is only possible for the manufacturer of the actual component. If this actual component is to be Integrated, it will require extensive cooperation between the component supplier and the system integrator.

But this again raises another ever-bigger problem:

The SW contains information that must be protected by the component supplier to protect intellectual property rights. It is not possible for a system integrator to be enlightened of certain smart system functions, without risking revealing this knowledge when implementing the similar control functions for a competitor in a different project. This is today the most obvious reason component suppliers refuse to give the control information to a system integrator.

5 IAS Design Philosophy

5.1 Time Utilization

When developing strategies on how to give the customer the best possible product, it is important to consider the utilization of your employees. With simple analysis, it will be apparent that to achieve the best possible utilization of time it is necessary that all bottlenecks of production are located and addressed.

An example of such a bottleneck may be that when installing an automation system aboard a ship, the shipyard will create a I/O-list of signals going in and out of the automation system and what functions they should have. Once this document has been created, it will be forwarded to the automation provider, whom has the task of setting up systems that can handle input signals and give the correct outputs based on the functions specified in the list. If this list is received and used directly in generation of program code, bottlenecks are being removed, compared to the task of manually synchronizing the list from the shipyard with the functions of the automation system. Another advantage is that IAS lists can be completed on a later stage in the project, making changes less likely. Change management can become a major cost when working on pilot projects like small-scale LNG. But there are many reasons why most automation suppliers do not generate the program code based on the shipyard I/O-list. One is the fact that most shipyards uses different format on their list and functions are specified differently, making decoding an issue. A standard format in use as an interface between shipyard and automation supplier reduces likelihood of misinterpreting and reduces total workload on the project, reducing cost and increasing quality as an effect.

An IAS supplier utilizing import tools that can take the I/O-list directly from the shipyard and import it into the IAS, thus eliminating this bottleneck will have a significant advantage compared to a supplier depending on manually synchronizing the two lists. Another advantage of this approach is that modifications to the I/O-list will be easy to update with the correct details per the requirements of authorities and ship-owners that will arise during the construction period.

The commissioning can also be divided into multiple steps where cable and termination lists can be made earlier in the project and I/O-checks can be performed concurrent with connection of physical signals. If the automation supplier also facilitates the possibility of the shipyard personnel to do I/O-checks, the automation supplier may reduce their effort on site. IAS service engineers may also set up a remote connection to the system, enabling them to work from the comfort of their offices. Travel and commissioning cost for the plant is reduced, while IAS engineers are utilized in a more efficient way which in turn leads to reduced cost for both shipyard and owner.

5.2 Failure Mode and Availability

To ensure that a PLC-based control system work and fail as intended, there are several challenges that must be addressed in conjunction with design and commissioning of a system. As we all know, hardware units will eventually fail, and the task then will be to limit the effects of such a fault. By analysing the effect of different HW faults, it will be clear which dependencies the different parts of the plant have between each other. During system design it is crucial that these issues are addressed to give the intended result, generally, as few as possible dependencies should be allowed.

5.2.1 Failure Mode

Another aspect to consider is failure mode. In shore-based industries where most PLCs originate, fail state will often be defined, to which the system will return to if something goes wrong. Most often, this state is stop, but on board a ship it can be dangerous to go to stop if, for instance, the vessel is in a critical part of the operation such as manoeuvring to the dock or navigation in narrow waters. It is important to define to which conditions the system should go to if something goes wrong. In many cases like a PMS, the safest way is to do nothing, a system fail will generate an alarm, but the system configuration will remain unchanged.

5.2.2 Availability

As we know from availability calculations the availability of a complete system in series is the product of all availability numbers, the product will always be lower than the individual components.

Let's consider the following example with a DP system of an LNG bunkering vessel operating in enclosed harbours. The DP system is connected to PMS, which in turn is connected to MSB.

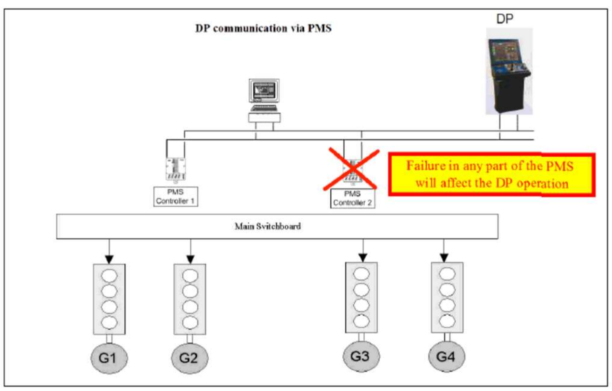
Given:

$A_{PMS} = 99\%$

$A_{MSB} = 99.98\%$

$A_{DP} = 99.99\%$

$A_{tot} = A_{DP} * A_{PMS} * A_{MSB} = 98.89\%$ which corresponds to 3.8 days' downtime in a year.



If we instead connect DP system directly to MSB we will get these numbers:

$A_{tot} = A_{DP} * A_{MSB} = 99.997\%$ which corresponds to 2.6 hours' downtime in a year.

A simple design change made a big impact on the result. This example underlines the importance of giving a thought to signal flow and dependencies and how it affects the availability of the total plant.

5.3 Spare Parts Availability

As marine automation systems operate on ships sailing worldwide, it is important to ensure that access to spare parts is sufficient. This is best achieved either by a supplier agreement, ensuring delivery time and availability in the ports the ship operates in, or that components that are available worldwide because they are also in use in shore-based industries are being used. The last option only requires one to make an active choice when selecting a vendor, while the first option requires continuous monitoring of system vendor service agreements. Another consideration that must be made is the design life of the plant. Ideally it would be cheapest to buy a plant, which can be maintained for the complete lifecycle of the vessel. This reduces the likelihood of a costly retrofit of the whole IAS at any point. Since many modern electronic components have a shorter design life than a ship it is worth considering making a lifecycle management assessment of the automation plant.

Generally, PLC's from well-reputed international vendors like Siemens, ABB and Honeywell have a LTS philosophy, which ensures systems can be maintained at least 20 years. When it comes to HMI computers these have a generally lower support life and spare part availability is generally poor beyond 10 years. Selecting a vendor with a good track record in lifecycle management of the plant will be beneficial. To ensure possibility for retrofit at a later stage, signal interfaces and sensor types should be selected according to industry standards to reduce costs if retrofit is necessary during the lifetime of the vessel. Using standard communication methods like OPC between PLC's and OS increases possibilities for part retrofits as apart of mid-lifecycle upgrade of vessel.

6 IAS Vendor Selection

6.1 General

To select the correct vendor out of the many who are available, a set of tools come in handy. Assessment of TCO can be performed as well as assessing the owner benefits of choosing a particular system vendor. The availability for the system to feed data to other systems such as maintenance systems, loading computers and owner specific databases containing big data from all ships should also to be considered.

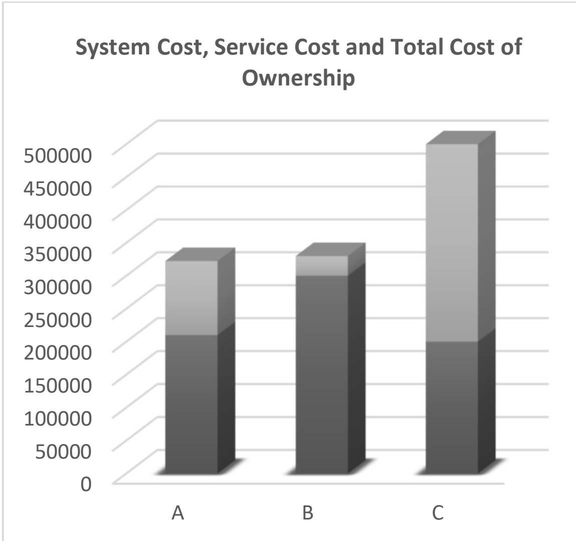
6.2 Total Cost of Ownership

There are several factors that affect the total cost of ownership of an automation system. The most obvious factors are purchase price and annual maintenance cost.

While initial purchase cost is easy to compare, annual service costs are more difficult to compare as different vendors promise a certain service level without necessarily committing to it in a contract. However, there are some things to look out for to make sure service costs are kept as low as possible. By using standardized hardware components available from well-reputed industrial equipment vendors, cost is kept low and quality and availability is kept high. The effect of using standard off-the-shelf hardware induces a reduced flexibility in the use of special signal interfaces, but the advantages are clear. On the software side there are also clear positive effects of choosing a standard platform instead of custom-made software structure tailored to ship applications. The things to look for to get as low as possible annual service costs are as follows:

- A reduced spare parts inventory is an obvious effect of standardizing an automation plant. Less spare parts needed on board reduces necessary storage space as well as it increases the likelihood of crew finding the correct spares when needed. It also ensures they are familiar with the equipment in such a way that they can troubleshoot and replace faulty units.
- Using standard software components based on IEC61131 code language also utilizes the maintenance staff in a better way, making them able to troubleshoot more effectively.
- Reduced on-boarding time for maintenance staff coming from other shipping companies and other automation segments is also a clear advantage of using standards. The reduced on-boarding time reduces training cost and makes sure that shipping companies can source crew with the right competence at the right time.
- When using standards, it is also easier to get third party support if there is an issue with the system. The use of third party service staff makes sure service cost rates is kept within industry standards.
- By using standard data transmission protocols interconnection to maintenance/operational and financial systems are commissioned cheaper and more with higher reliability.
- The availability of remote support reduces MTTR as well as reducing travel cost.

Consider the following example of an automation system delivered from Vendor A, B, and C:



Ven-dor	System cost [USD]	Service cost [USD]	TCO [USD]	Service cost [USD/Y]	Design Life [Y]	TCO/ Year
A	210000	112500	322500	7500	15	21500
B	300000	30000	330000	2000	15	22000
C	200000	300000	500000	20000	15	33333

Looking at the charts it is obvious that selecting vendor A gives us the lowest TCO, while vendor B gives us the lowest service costs and vendor C has the lowest outright system purchase price. Using TCO as the only criteria, vendor A will be selected, but if initial financing is an issue, vendor C can be selected. The best choice here would be to select vendor B, since service costs are the lowest. The reason is that service requests often are triggered by system failure which, when selecting a vendor with high service cost induces an increased MTTR and a decreased MTBF which reduces the total availability of the system and the operational availability of the vessel is being reduced. This is often impacting the total revenues of the shipping company in much higher proportions than automation system TCO.

6.3 Data Logging

As a superior control system has access to all properties in the database of any signal in the system, it is often an easy task to set up a detailed log of the I/O signals.

A sub-control system may today connect to hundreds of sensors, and control many important outputs. Each of the I/O signals contain a lot of properties, such as Time Delay, Alarm Limit, Filter Factor, Hysteresis etc.

To save money on the interface to the IAS, only a few of these signals are selected for the communication, and thus available for presentation. Logging a debugging in IAS, raw values from IO are often not transferred. This is often limiting the possibilities to investigate actual actions and possible SW bugs after an incident.

Data logging of signals has increased both in terms of the time domain and by adding a wider spectacle of variables to the data logging system the later years. Earlier on this data was used mainly to display trend windows and for playback functionality, a function which lets the operator play back historic events using the same mimics as the operator station normally uses, much like a PVR decoder on a TV.

6.4 Performance Optimization

As much as functionality like playback and trending is a very powerful troubleshooting tool, the data stored is now also used to optimize energy consumption and to propose optimum operation of vessel power plant.

Another aspect of this development is that ship operators gather data from both their ship operations as well as logistics and freight departments and use this data to optimize their revenues.

7 Specification Guidelines

7.1 General

To get the best possible automation plant on board a vessel there are a few guidelines that can be followed when specifying automation plants to ensure that necessary thought is behind the selection. After delivery of the vessel, the Yard should provide a list of all systems containing a PLC.

7.2 Hardware Requirements

As we will have to live with different types of control systems in a plant, we will need to set basic system requirements corresponding to the level of integration we desire.

A PLC will eventually fail and if, after 10-20 years the suppliers are not able to provide spare parts, the whole system will have to be replaced. Depending on whether the previous vendor used standard software, it might be possible to port the software to run on a different PLC. This is however dependant on available backup of the actual system, and this backup must of course be extracted from PLC before it’s failing and it is also only possible using PLC manufacturers programming cables and software.

Since a PLC is cheaper than relays, all suppliers will generally want to control their components with a PLC, but this must be limited to a certain degree. The specification should define where a PLC is accepted and not.

A common PLC brand should be specified if possible. The owner should try to keep the PLC brands as standard as possible to avoid difficulties and high costs in future maintenance.

7.3 Sub-system PLC Criteria

During development of the specifications as well as under ship construction, the owners need to execute control over which control systems that are allowed containing PLC´s and which are finally chosen. Typical questions should be:

- Why a sub-system needs a PLC based control system on its own?
- Why can it not be controlled from IAS with standard I/O?
- How will the system be supported during service?
- Is there an obsolescence plan?

Answers justifying the installation of a sub-system PLC:

- The number of signals connected > 100
- The unit contains advanced logics made by the equipment supplier
- The unit has special demands for safe operation, and shutdown
- The system requires local operation independent of the IAS (redundancy aspect)
- The process logic is extensive and is developed under another brand
- The commissioning engineer from the supplier must be able to make SW modifications

7.4 Software Requirements

When a subsystem is accepted, there should be set some basic requirements for all SW. Following items to be delivered along with the system:

- Backup and Listing of the installed SW to be provided
- SW maintenance routines to be available
- SW Version Number
- List of ALL parameters after delivery (if any)
- A complete I/O list of all signals with detailed properties to be provided
- SW code listing (file, PDF or source code)
- FDS of the functions in the delivered system

7.5 Maintenance Requirements

- All HW must be available off the shelf for (10-15 years)
- List of all installed HW with supplier information
- Spare batteries (if any)
- Special tools for parameter or SW Adjustment / Upload

7.6 Interface Requirements

- No common alarm should be accepted from a standalone system with multiple alarms.
- If a common alarm from sub system containing multiple alarms must be accepted, the output should at least pulse every time a new alarm is activated to notify the IAS about the new alarm
- Standard communication bus to be available. (If applicable)
- A list of all available signals for superior communication with defined addresses. (If applicable)

8 Case Study MV Cardissa

8.1 General

MV Cardissa is a LNG bunkering vessel operating for Shell Western LNG. This is a new type small-scale LNG vessel, which has a cargo capacity of 6800 m³ of LNG. The total length is 120m and the beam 19 m. The shipyard building the vessel was STX, Korea and ship was delivered spring 2017.

8.2 Project Execution

Høglund Marine Automation delivered the IAS system together with PMS for this vessel and since it was a new development, it was necessary to change many details from initial specifications.

While most of the components installed on board was standard components, the way they were to be used differentiated from standard operation principles. HMA used its software knowledge to customize the system to give the operators the overview of the plant while ensuring control loops were working as intended.

One example of this method of working is the way fuel consumption from boilers, engines and GCU are measured and reported to assist the CTS in calculating delivered LNG fuel when bunkering LNG-powered vessels. Since the CTS system was a standard delivery, it was not that easy to add another calculation to the system, but the equation was known and IAS had the data - therefore the function was implemented there.

Another example is from a test of the gas to FO changeover of the MG sets, which was performed during sea trail with full load on the generators. The test was performed by closing of GVU, and ended in a total blackout, which was not anticipated. It turned out that there was a time delay between gas supply loss and automatic changeover to FO in the control system of the MG sets, which caused the problem. The solution was for the IAS to send a notification to MG set control system as soon as gas supply was turned off, making the changeover to FO instant, thus avoiding a total blackout. HMA implemented the function right away system was retested and approved.

9 Conclusion

We have now shared some of our insight when it comes to automation system design, development, work methods and interface to other systems. When applying automation to new segments like small-scale LNG, an integrated approach will be technically beneficial to get the system, which perform in a way, anticipated by the operator. This new business segment is dependent on cheaper solutions to thrive and therefore it will be beneficial to use industrial standards at a high degree to minimize development costs and to make the systems future proof.

We have seen that an ever-increasing pace in the market leaves little time to specify the details when it comes to automation integration philosophy and therefore a high degree of selectiveness of vendor based on previous deliveries is applied, instead of having a general specification for more suppliers to compete against each other.

It is important to remember that even the biggest suppliers, with the most integrated systems, are basically a conglomerate of small vendors competing under the same logo.

By splitting up the control packages and defining interfaces between different systems, the control strategy becomes clearer and the risk is decreased. This philosophy is also used internally in some companies to increase portability of code and section the project between different software engineers specialising in their domain. Høglund is applying this technique to get the best possible SW product delivered to market. By focusing solely on SW, and letting others develop HW, both disciplines gain and the product becomes better than the two disciplines alone.