Integrated Platform Management Systems and Ships staff – How to keep them working together

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Synopsis

The trend in recent years has been to increase the boundary's in IPMS capabilities making them more and more complicated with more and more Inputs & Outputs (IO) being monitored and controlled. This is all well and good if the system is a really good one, which has been well engineered, well installed, commissioned even better and then maintained to a high level – then the ships staff could be confident that the system is telling them the truth and will do what is asked of it (in regard to Automatic functions) and what they ask of it.
If the system is lacking in any way, then trust will be replaced with mistrust and the IPMS will become an expensive liability.
This paper will explore the boundaries of an IPMS system and make reasoned recommendations for how a system should in the opinion of the author be designed, built, tested and maintained. This will include discussing the following aspects:
What is the detailed Aim/Purpose of the system – what is the system needed to do, so that we can decide what is essential and what is possibly 'nice to have'
Inputs and Outputs to be included – more is not necessarily best and how are they to be brought into the system

Equipment Selection – Commercial off the Shelf (COTS) or Bespoke
Visualisation software – COTS or Bespoke
Control software – how should this be written/created
Building and Testing standards
Installation standards
Commissioning

Through Life Maintenance – the aim is to be able to keep the existing system working though the life of the ship with simple upgrades and exchanges

Keywords: IPMS, Automatic Control, COTS, SCADA, EtherNet/IP

1. Introduction

In recent years Machinery Control and Automation Systems (MCAS) have been replaced by Platform Management Systems (PMS) and then Integrated Platform Management Systems (IPMS), the benefits that these systems can give to a ship in terms of reduced manpower, better control and improved safety can be enormous, but if the system has any weaknesses these will quickly be exposed, and the system can become a real safety concern. This paper attempts to provide a guide to best practice from design through installation and commissioning to through life maintenance. It should be noted that this paper is referring to large IPMS systems and not smaller alarm or alarm and control systems for which there are numerous good quality bespoke systems available.

2. Hardware selection

The first question is should the system be made from a company's own design hardware or from Commercial Off the Shelf (COTS) Industrial Automation hardware. The main benefits of using 'in house' hardware is that the company has more control over the supply of the hardware, more profit can be made, or a lower price can be charged. The main disadvantage is that the hardware will not have many hours of proven use when compared to

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COTS hardware which has been operating in numerous high pressure production lines for years – the blue chip manufacturers will not tolerate hardware failure or equipment which quickly becomes obsolete without a simple upgrade path, so successful blue chip Automation Companies supply hardware which is extremely reliable and long lived (there is an exception to this with several Japanese ranges being made obsolete early due to factory damage during the Earthquake & Tsunami in 2011) usually with simple migration tools to move software over to replacement hardware ranges. COTS hardware will also benefit from software tools which are easy to use and well tested. If signed up to manufacturer updates, several years notice of a product coming to 'end of life' will be issued along with upgrade paths, so the owner can select to either purchase enough spares to see the platform through to decommissioning or plan an upgrade.

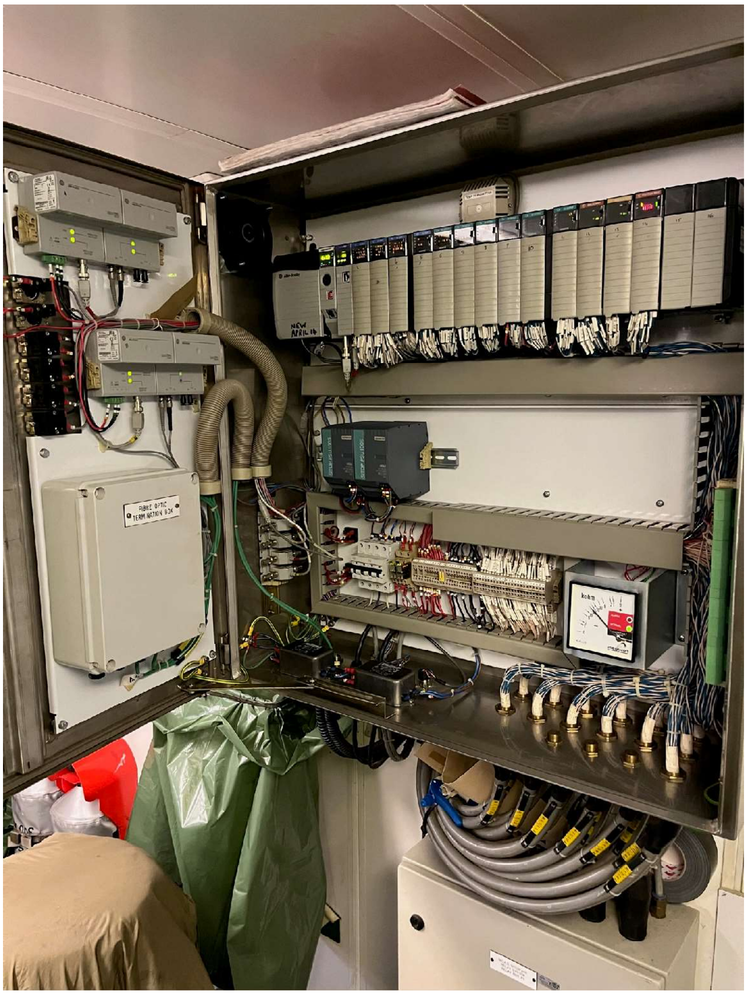

Figure 1.

Figure 1 above shows a picture taken in May 2022 of a outstation which was installed in 2001, this has been performing well over its current 21 year in service life and could easily continue for another 15 years – this longevity is largely due to the hardware selection insisted on by the owner at the tendering stage.

With regard to using COTS hardware in Military applications, most hardware will have 'Marine Type Approval' requiring demanding specifications for Electromagnetic Compatibility, Vibration, Temperature and Humidity to be passed, it can also be ordered with a 'Conformal Coating' which will reduce the effects of damp salt laden atmospheres, spring loaded terminals should be selected over 'screw' type, physical locking bars can be added to stop the possibility of components 'jumping' off of mounting rails if a physical shock occurs, enclosures should be built to meet the environmental demands and should be mounted with correctly sized shock mounts.

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Costs can be saved by using Personal Computer (PC) based 'Soft Programmable Logic Controllers (SPLC)' a PC however will not be as reliable as a dedicated Programmable Logic Controller (PLC). PLCs would be expected to run without fault or interruption between 5-year refits, it is unlikely that many PCs can match that.

Then there is the physical configuration of the hardware to consider, many systems make extensive use of Remote Input Output (RIO), these can save a lot of cable during the installation phase and do not need a local processor, just a communications module, the issue with RIO is when it is being used for control, if the communication link to the PLC which 'owns' this RIO fails then the control is lost, the RIO having no local intelligence to be able to work out the best course of action.

Secure power supplies which will carry on running in the event of a blackout for over 1 hour are very important and must factor in the hardware selection, along with isolated supplies, extensive discrimination of circuits and earth leakage detection.

From this evaluation it can be seen that, the use of COTS industrial automation hardware, dedicated PLCs, RIO only to be used for monitoring, unless the communication to the PLC is multi-redundant, would provide a good basis for an IPMS.

3. Software selection

The programming software usually consists of the PLC Software and the Visualisation Software. Any software for 'in house' hardware is not going to have had as much development time and 'testing in use' as the software used to program the COTS industrial PLCs – extensive use of software in high pressure environments will ensure a very reliable software tool, the aim is always to clear all the bugs before general release, with yearly version upgrades for new and improved features. For COTS hardware the software tool to use is generally dictated - so once the hardware has been selected the Programming tool is also selected, therefore the facilities and ease of use of this becomes a factor in the selection of the hardware.

Regarding the Visualisation software this is often referred to as Surveillance Control and Data Acquisition (SCADA) software. In house SCADA will not have seen as much in use testing as COTS SCADA from Industrial Automation suppliers, often in house software has to be compiled after each change – however small, if version control is not 100% there is a recipe for disaster, there are numerous examples of corrections made during the previous tranche of work lost when a new batch of corrections have been made – this really tries the patience of ships engineers and damages their confidence in the system. With COTS SCADA packages the configuration tool allows the system to be built up progressively, reliably, and most have 'bolt on' version control modules. Hardware selection does not mandate the SCADA selection, most SCADA systems will work with any recognised COTS hardware e.g. within the Royal Fleet Auxiliary (RFA) Fleet there are a class of ships with Allen Bradley Hardware and a GE Fanuc SCADA. The SCADA software licenses usually dictate the number of Tags that can be used, and it is important to select software and hardware which has a maximum limit much higher than the projected tag count for the system, if lower capacity licenses are purchased then these can easily be upgraded to higher tag counts later providing that the hardware can support the higher tag counts, 100,000 tags are not uncommon maximums.

The author would strongly recommend that a COTS Programming tool and recognised Industrial SCADA package is used. Further the owner will benefit from being granted the Intellectual Property Rights (IPR) for the project software so instead of being restricted to using the Original Equipment Manufacturer (OEM)/System Integrator (SI) for upgrades they can if need to use another qualified System Integrator (SI). This will stop the owner being 'held to ransom' if changes are needed or forced to purchase a new system if the original OEM/SI stops trading.

4. Communications architecture

Twenty-five years ago, designers of control systems would advise to use deterministic open architecture networks such as ControlNet, Profibus, CC Link and others, each major automation supplier had developed their own and then put policies in place for them to be declared as 'open'. Now although most of these networks are still in use we are being encouraged to move over to EtherNet/Industrial Protocol (IP) Networks, software has been developed to allow these to be deterministic and with much greater bandwidth than the early deterministic networks. So now all manufacturers seem to have settled on EtherNet/IP as the standard for communications. With this in mind the architecture becomes a question of Switches, Topology and Media.

Any weakness in the design, quality of components, setup or installation of the network will quickly become apparent, so it is important to select really good quality switches, to choose the correct speed (it is no use having a section running at 100MHz if 1GHz is needed) and a topology which has some level of resilience. A ring which can be supported by managed switches will repair itself if one section of the ring is damaged. If each device can take data from two different switches a switch failure does not mean lost data. A double ring with each device taking data from each ring provides even greater failure resilience.

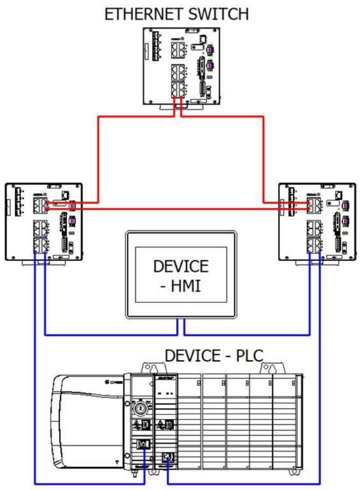

Figure 2.

Figure 2 shows a basic example of a redundant ring network with a redundant node device, this can carry on working in the event of both a single failure on the ring and a failure of a switch.

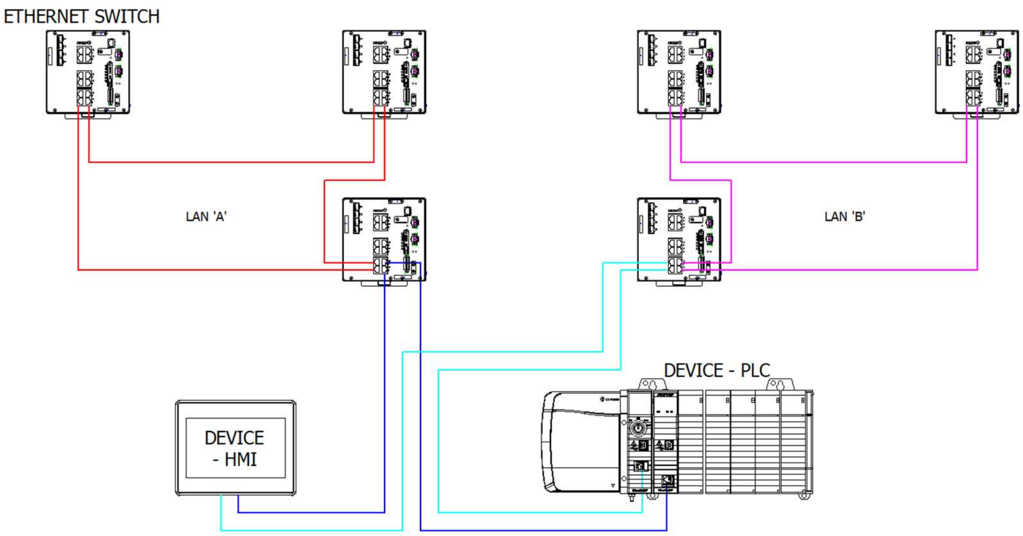

Figure 3.

Figure 3 show a basic example of a dual redundant ring network with redundant node devices. This can carry on working in the event of a total network failure, a fault on each ring and the failure of a switch.

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With damage control zones to consider additional rings could be added.

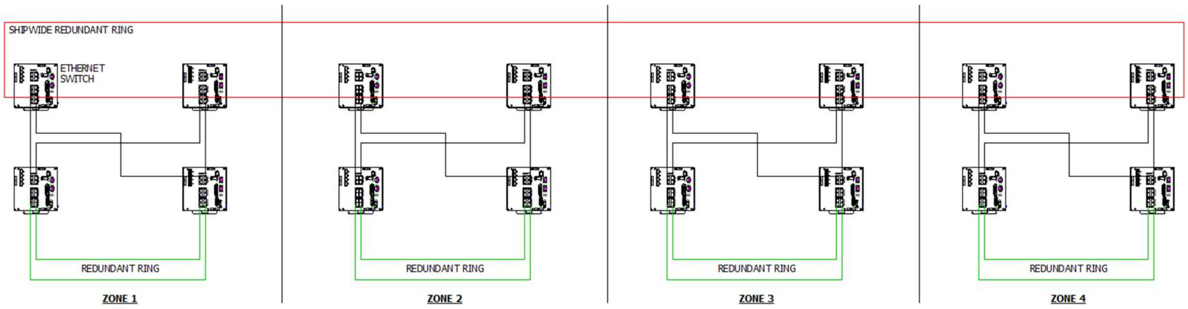

Figure 4.

Figure 4 show a network example with a redundant ring in each damage control zone which are connected to an overall ship wide redundant ring. If the hardware is positioned and configured correctly the zones will be able to work independently, should they get separated from the ship wide ring and equally the ship wide ring will be able to continue operation with the loss of a zone.

A dual redundant ring is much more expensive to build but would provide more resilience to failure providing it is carefully planned, designed, installed, and set up. It is important to properly quantify and understand the amount of resilience that is really required and then design the Architecture accordingly – it should be noted that the more switches and complication in a network the more time it will require to start running properly and the more internal resources will be used just on overhead tasks, the skills of future maintainers also need to be considered and risks mitigated – perhaps by not making it overly complicated.

5. Tag numbering structure

Sensors and internally generated data need to be provided with tag names for identification purposes within the software, on the mimic diagrams, on drawings and in the manuals. A well thought out tag numbering scheme will be a real through life benefit to the system, one such example is detailed below:

The tag 11LIAL14005 is made up of 4 sections,

Number1	Number2	Signal Type	Number3
1	1	LIAL1	4005

Number 1 is used to signify the main system group that the tag belongs to,
This shows the tag is for the Port Main Engine e.g.

0 = SME
1 = PME
2 = Machinery Auxiliaries
3 = Electrical Distribution
4 = Power Generation
5 = Cargo
6 = Fire Systems
7 = Bilge
8 = Deck
9 = System

Number 2 is used to signify the sub-group for that main group,
For the example tag the sub-groups are:

0 = General
1 = Gearbox
2 = Clutch

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Signal type is LIAL1,
This is standard instrumentation code so LIAL1 = Level Indicating Alarm Low and the 1 indicates the first instance of this type of signal on this asset.

Number 3 is 4005,
This is the asset number (which always consists of 4 numbers) in this example the PME Gearbox is asset 4005

So, without even a description we know from the tag that 11LIAL14005 is an Analogue Level Alarm Low for the Port Main Engine Gearbox.

A further benefit of this tag structure is that the tags can be easily sorted into relevant groups. One disadvantage could be that you can only have 10 main system groups available, to get over this a hyphen or underscore could be added e.g., 13_1LIAL16007

It is very important that this tag structure is agreed with the owners and shipyard, so it becomes consistent though all of the ship's manuals and documentation, not just the IPMS.

6. Location Codes

On large, complicated ships, finding the location of IPMS sensors and other hardware can be a challenge and take up a lot of man hours. A useful tool to increase efficiency is to add a meaningful location code within the drawings and documentation, one such code is detailed below.

Location code C155P03

This location code is made up of 3 elements:

The letter describes the deck, with 'A' being the keel, '155' being the frame number and 'P03' being the distance from the center line in meters either Port or Stbd. So, the location code above indicates the 2nd deck up from the keel, at frame 155 and 3 metres Port of midships – this allows locations to be narrowed down to a 1m cube.

7. Software Integration and Documentation

For reliability of operation, the control software should be made up of building blocks, each block being thoroughly tested prior to duplication. The sub system software can then be made up of these building blocks which are configured to suit the application needed.

Documentation is then key because the engineers who wrote the software will move on and if they stay it is likely that they will forget so a few months down the road the documentation will be vital to confirm how the systems should operate.

The documentation for each building block should include details of:

- Inputs
- Outputs
- Adjustable parameters
- Alarms
- A summary of what the block is intended to control (e.g., Pump, Valve, Clutch etc)
- A detailed description of how the block works with all interdependences explained.

The documentation for the sub system software should then detail what the subsystem is designed to do, which building blocks and how many of each are used, the nominal/recommended settings of all the adjustable parameters and a drawing showing how the building blocks are connected within the software. Figure 5. below shows the physical interdependences of one half of the Jacket Water pump control system. The following are included:

- Tag Numbers
- Direction of signal travel
- Outstation number (E3)
- Software Blocks used (C73 & C13)

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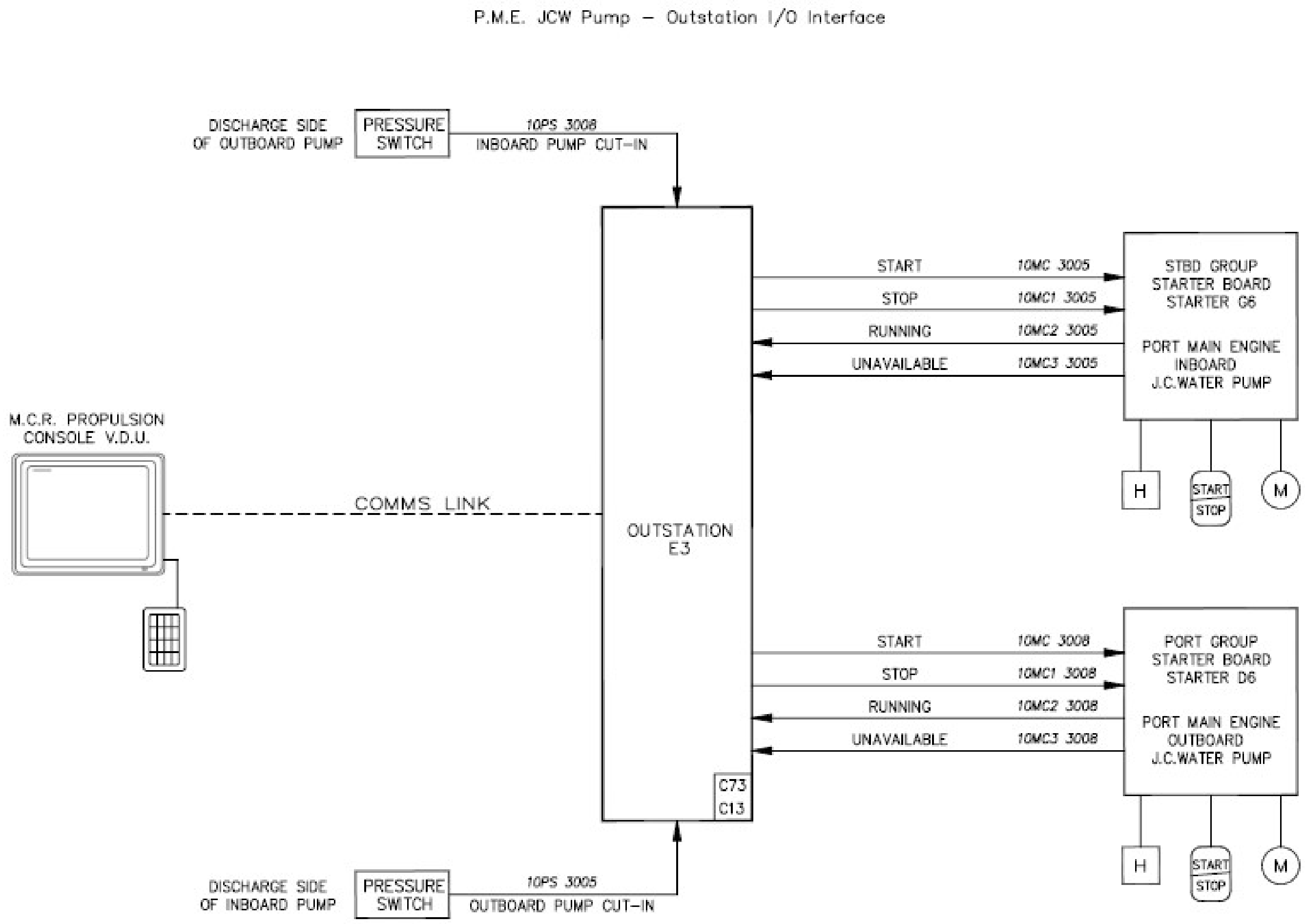

Figure 5.

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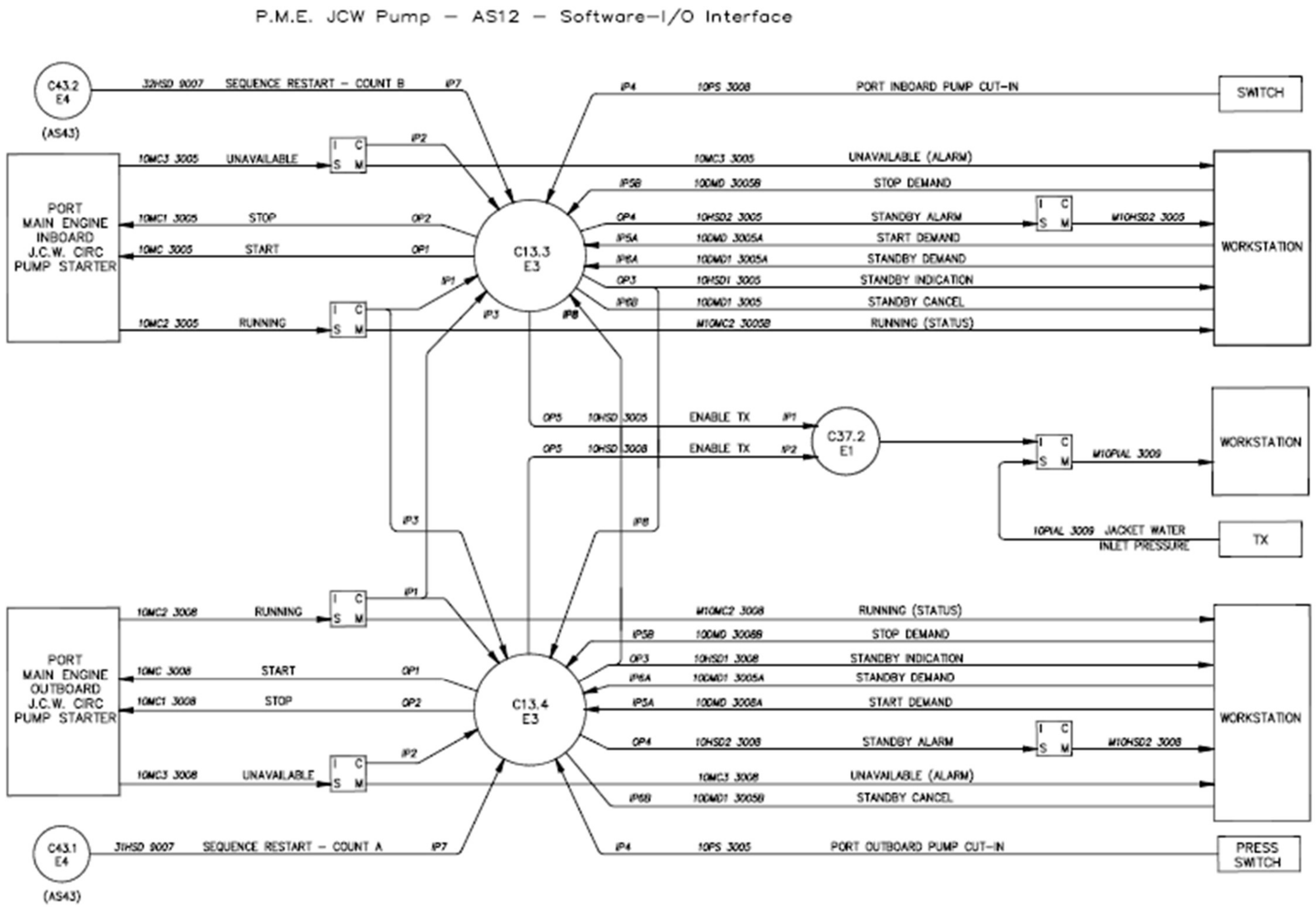

Figure 6.

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This is then complemented by the software I/O interface drawing Figure 6. (this was nicknamed 'The Bubble Drawing' for obvious reasons) which shows exactly which software blocks are used and how their inputs and outputs are connected. The outstation number for each software block is included, the unique software block index number is included. Arrows are used to so the signal direction.

This level of detail is essential for effective operation and maintenance through the life of the ship which will be 30-40 years and encounter many different sailors in each role. For example if an engineer calls out an Electro Technical Office (ETO) or Systems engineer (SE) to ask why 6 standby High Pressure Sea Water (HPSW) pumps started after the HPSW main pressure dropped, it is unlikely that they would know the answer to this question, but they should be able to read the sub system description and that should be able to tell them that – 'in the event of a pressure drop or a flow sensor being activated up to X number of standby HPSW pumps will start sequentially, with X being a configurable parameter which we recommend is set to 6'. If this documentation is not in place, the owner will end up calling out the OEM to ask that question, the OEM will then spend several hours looking through the software to hopefully come up with the same but expensive answer.

8. System boundaries

It is important not to bring IO into the system just because it is available, e.g. A purifier has a local operator panel and the option of a data link to the IPMS, and it also has a physical output to indicate running and fault. It can be argued that all the IPMS needs to know is if it is running or if it is faulty, there is little point being able to know from IPMS what the fault is because the engineer will have to go down and work on the purifier to sort out the problem. Equally the data links from Diesel Generators can easily include over 300 data values, the IPMS should restrict the data values used to the essential ones which are needed for a general overview of operation, so temperatures, pressures, speeds and levels, anything else if in alarm will raise the Common Alarm and the engineer has got to go down to the generator to investigate and resolve. In the same breath IPMS should be used to monitor and advise on all ships systems so for example all detector heads on the fire detection system should be indicated individually, this will allow any IPMS workstation around the ship to have full visibility of fire status. This common sense and critical approach will result in the minimum number of IO really needed, which could still be over 10,000 and mean that alarms which occur really do need to be dealt with and not ignored.

9. Control strategies

It is important that control strategies are consistent through the IPMS, so here the IPMS team need to ensure that the ship designers and procurement team know what those control strategies are and are actively encouraged to ensure they are met. e.g.

Pumps and Fans – a pulse to start and a pulse to stop, a closed contact for running and an open contact for fault.

Fail in position valves – an open signal until the open feedback is closed (plus a seating time) then the open signal is de-energised, a closed signal until the closed feedback is closed (plus a seating time) then the closed signal is de-energised.

Ideally once IPMS has made the control command and it has been affected then the IPMS outputs should be dormant. This cannot be the case with analogue outputs, but again analogue outputs should all be consistent e.g., an increasing output will increase the temperature, pressure, speed of whatever is being controlled.

10. IO Drawing information

IO drawings should be for the benefit of future maintainers not the wiremen installing the system, so that one drawing should be available to show the wiring of a signal from sensor through to the PLC rack. It is not efficient for a maintainer to have to get out 3 or 4 cable wiring drawings in order to follow a sensor back to the PLC. These drawings can take the form of a table as per the example shown in figure 7. which can hold a lot of information in one row i.e.

IO Channel on the module, Tag Number of the device, device description, device location, local connection terminals.

Cable Number, cable cores, junction box name and location, terminals, and outgoing cable number/core outstation number, terminal block and terminals, outstation location, rack, card slot and 24V fuse, terminal, wire number and what type of signal.

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Channel	FIELD DEVICE				JUNCTION BOX						OUTSTATION E3							
	TAG NO.	DESCRIPTION	LOCATION	TERMS	CABLE	CORE	JB	LOCATION	TERMS	CABLE / CORE	TB	TERMS	LOCATION	RACK	SLOT / FUSE	TERMINAL	WIRE NO	INPUT / OUTPUT
0	10MC2 3005	PME JCW PUMP INBD RUNNING	B176P05	1	HPA1001	1	E3-1	B178P00	1	HPA101-1	2	1	E165S02	1	2	1	10MC23005	INPUT
				2		2			2	HPA101-2		2			FB2-1			
1	10MC3 3005	PME JCW PUMP INBD UNAVAILABLE	B176P05	3	HPA1001	3	E3-1	B178P00	3	HPA101-3	2	3	E165S02	1	2	2	10MC33005	INPUT
				4		4			4	HPA101-4		4			FB2-1			
2	10MC2 3008	PME JCW PUMP OUTBD RUNNING	B176P03	1	HPA1002	1	E3-1	B178P00	5	HPA101-5	2	5	E165S02	1	2	3	10MC23008	INPUT
				2		2			6	HPA101-6		6			FB2-1			
3	10MC3 3008	PME JCW PUMP OUTBD UNAVAILABLE	B176P03	3	HPA1002	3	E3-1	B178P00	7	HPA101-7	2	7	E165S02	1	2	4	10MC33008	INPUT
				4		4			8	HPA101-8		8			FB2-1			
4	10PS 3008	PME JCW PUMP OUTBD PRESSURE LOW	B176P03	1	HPA1004	1	E301	B178P00	9	HPA101-9	2	9	E165S02	1	2	5	10PS3008	INPUT
				2		2			10	HPA101-10		10			FB2-1			

Figure 7.

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11. Physical installation of the system

Assuming the general installation is carried out to a good standard, which must be inspected carefully, the installation needs to take into account environment and vicinity to other sources of power.

Environment – the IP protection and material of the enclosures should be commensurate with the environmental conditions, 316 Stainless should be used in favour of 304, mild steel should be avoided, and aluminium should be properly protected to avoid corrosion. Operating temperatures must be considered as increased temperature will reduce the life of electronic circuits, AC systems fitted to enclosures will reduce this issue if high ambient temperatures cannot be avoided but they present another maintenance task. Stainless steel has a long life but does not dissipate heat very well.

Vicinity – Signal and communications cables must be suitably separated from high power and high voltage cables. Enclosures should be located away from heavily used through routes and protected from above by a deck, ideally there should not be any pipes carrying fluids which could leak or spray over the IPMS enclosures – although the IP rating should be sufficient in normal circumstances, if the enclosure is open for maintenance or has not been closed properly water leakage will be a serious problem, again the commissioning engineer, class surveyor and owner should all take the time to inspect the installation with a critical eye and not be afraid to insist on it being re-worked.

12. Physical installation of the IO

The shipyard must be instructed on good practice for the installation of sensors. Installations below deck plates should be avoided, suitable means of isolation must be provided for all pressure instruments which should be mounted where possible on separate plates on bulkheads at about waist height. Temperature probes should be isolated from the process by pockets and where heavy vibration is likely the connection to the field wiring should be in a separately mounted junction box instead of the head of a temperature probe. Level switches should be selected and installed so the body will not normally become submerged. If pressure type level sensors are to be used these should be installed either by stilling pipes on the top of the tank, or via isolation valves on the bottom side of the tank – tank entry should not be needed to check calibration or to replace these sensors. Radar sensors should not be used on tanks of less than 4m height or on tanks which could have mixed contents e.g. Slops tanks (the radar could pick up an interface level instead of the top of the liquid if not set up really well). Ideally there should be commonality between sensors of a similar duty – so select a good quality range of pressure sensors and use these throughout. All sensors should be clearly labelled with the tag number on a label which is securely fastened to the mounting plate, junction box or installed field cable so it is not lost over time.

13. Commissioning

It is critical that all aspects of the system are fully proved during the commissioning phase. To that end a fully detailed commissioning procedure must be produced, checked by all stakeholders and then the time and trouble must be taken to ensure all tests are thoroughly completed and signed off even if this means delaying the ship. If the system and installation are good this can be a quick process, the MCAS upgrade on RFA Fort Victoria with circa 4000 IO was thoroughly commissioned in less than 4 weeks, mainly because most tests worked first time.

14. Through life maintenance

There should be no reason why a good IPMS system cannot be supported for over 30 years, though it must be realised that the original equipment is unlikely to last for 30 years, so a realistic plan of replacement must be made to ensure replacement before failure but also with good value for money. To that end the following plan could be adopted or amended:

Daily - Earths traced and repaired when they occur
Any system fault alarms to be investigated and rectified

Yearly– UPS checked for autonomy by removing incoming supplies, batteries to be replaced when the autonomy is less than 60% of original
All critical sensors to be checked for correct operation, terminals at the sensor to be checked for tightness
20% of non-critical sensors to be checked so all are checked in a 5-year period, terminals at the sensors to be checked for tightness
The physical integrity of all hardware to be checked
Cables to be inspected for signs of damage
Fans to be checked and filters to be replaced/cleaned

2.5 Yearly- Additional to yearly
All terminals to be checked for tightness (by pulling cables)

5 Yearly- Additional to previous tasks
Workstations and servers to be maintained, including PSUs, fans, and Solid-State Hard Disks (SSHD) to be replaced, CPU Heatsinks to be re seated with new heatsink compound.
All other Power supplies to be replaced.
PLC batteries or SD/Flash cards to be replaced

10 Yearly- Additional to previous tasks
Workstations and servers to be renewed
PLC Processors to be renewed

15 Yearly- Additional to previous tasks
All other PLC Hardware to be renewed
All Communication Network hardware to be renewed

The above plan will take some level of resource to carry out, but it will ensure a very high level of system availability, additionally because work is being carried out regularly it will maintain the skill levels of the maintainers.

15. Conclusions

From the previous 14 sections the conclusion is, that a good IPMS is not easy to achieve, and requires the owner to understand what IPMS is needed to do and to fully engage with the supplier, shipyard and designer to ensure that nothing is left to chance.

If the owner does not take the selection, design, IO boundaries, installation, commissioning and through life maintenance of an IPMS system seriously and to a level advocated in this paper, then they may be better advised to go back to the automation levels of the 1950s and 1960s and invest in more engineering staff to carry out watchkeeping 24 hours a day.

On the other hand, a well implemented IPMS though potentially more expensive (in the short term) and with a large burden on the owner during the design and build stage, will be an asset to the ship, allowing safe reduced manning, accurately logging trends, which can be analysed for signs of wear and imbalance, reliably reporting status/problems and reacting correctly to avoid expensive machinery breakdowns and safety issues.

Acknowledgements

The views expressed in this paper are that of the author.

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