AUTONOMIC CONTROL SYSTEM UTILIZING SMART VALVE TECHNOLOGY

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ABSTRACT

As the level of integration across and between shipboard systems has increased in recent years, there has been greater emphasis on strategies to improve situational awareness, survivability under damage conditions, crew reduction initiatives, Damage Assessment, and Damage Action Management System (DAMS) as well as agent based automation. The above objectives necessitate consideration of an Autonomic Control System with improved intelligence that includes autonomous decision making by hardware with embedded intelligence. Furthermore, to increase survivability, consideration must be given to continued operation of the intelligent agents independent of the Integrated Platform Management System (IPMS), its high level automation hardware/software and its related data communication networks. In this paper, the authors present the application of an advanced Autonomic Control System (ACS) utilizing smart valve technology in the Chilled Water System and Fire Main System to provide highly survivable services critical to the operations of the ship's combat systems as well as Damage Control Systems.

KEY WORDS

Integrated Platform Management System (IPMS), Man-Machine Interface (MMI), Autonomic Control System (ACS), Autonomic Fire Suppression System (AFSS), Data Acquisition Units (DAU), Battle Damage Control System (BDCS), Local Operator Panel (LOP), Chilled Water System (CWS), Fire Main System (FMS).

1. INTRODUCTION

Integrated Platform Management Systems (IPMS) and marine vessel designs for both commercial and military vessels have become increasingly complex, resulting in higher automation levels that provide superior situational awareness and effective remote control and monitoring capabilities, thereby enabling reduced manning. Advancements in Battle Damage Control System (BDCS) functionality have further resulted in increased survivability and reduced manning under both normal operations and during casualty incidents. The IPMS distributed control system approach, with greater hardware redundancy at the levels of the Data Acquisition Units (DAUs), Data Communication Network Configuration, Human-Machine Interface (HMI), etc. have further resulted in improved overall ship survivability compared to the earlier Client-Server Architecture.

Further survivability improvement approaches have also been noted in the area of Autonomic Fire Suppression Systems (AFSS). However, for high-value vessels such as mission critical Military Surface Ships, Submarines, LNGs and Cruise Ships, technology can be applied to a modern control system to achieve a high level of overall Survivability during severe damage incidents. Such designs enhance the AFSS concepts to include Smart Valve Technology and apply the technology to other critical ship subsystems; such as the Fuel system, Fire Main System (FMS), Chilled Water System (CWS), and other relevant fluid systems where damage to the fluid system or damage to the IPMS main hardware (data network, consoles, DAUs) impacts a ship subsystem operational capability.

This collaborative paper presents the concepts considered by L-3 MAPPS in its design and implementation of a proven Autonomic Control System (ACS) algorithm that includes Smart Valve technology as an integral part of the L-3 MAPPS IPMS for a target ship acquisition program.

2. SURVIVABILITY ENABLED SYSTEMS

The L-3 MAPPS IPMS is based on Distributed Control System architecture and is already equipped with a pioneering widely used and world renowned Battle Damage Control System (BDCS) which includes various survivability enabling technologies. Some of these are addressed below.

Starting with a conventional IPMS configuration (Figure 1), the configuration consists of three (3) distinct levels without any embedded data networks; Man-Machine Interface (MMI) for systems monitoring & commands, Data Communication Network for equipment interfaces, Data Acquisition and Control level for MMI & Plant interfaces. Various redundancies at the hardware level (DAUs, Consoles, Local Operator Panels (LOPs)) ensure higher survivability in the event of unforeseen incidents during normal operations or, with adequate separation, equipment failure as a result of a structural damage when in combat.

In addition, the inclusion of advanced BDCS capabilities such as the Asset Management System utilizing image processing techniques on CCTV Real-Time images from monitored locations enables improved situational awareness and can result in improved ship equipment and crew survivability due to rapid Damage Action Management. In this case, while complementing the integrated fire/smoke detection system, the BDCS Asset Management System can identify fire/smoke incidents at a faster rate than fire/smoke sensors.

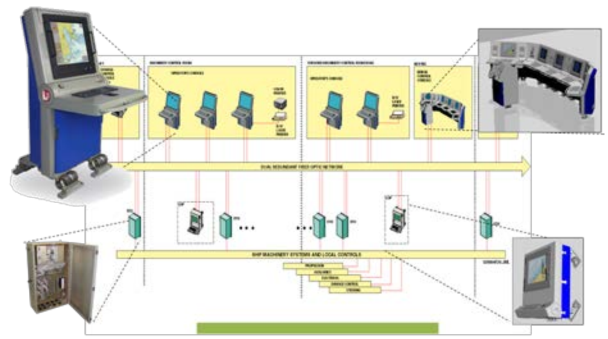

Figure 1: Typical IPMS Configuration

The Asset Management's digital image processing capability also detects flooding, motion and steam/major leakages due to a burst pipe. The L-3 MAPPS advanced Damage Action Management System component of the BDCS can interface with predefined Killcards to initiate automatic actions and procedures that are pre-programmed in appropriate Killcards (See Figure 2).

These features improve ship survivability even with reduced manning.

Figure 2: Asset Management Smart Vision System

The L-3 MAPPS BDCS provides other survivability improvement functions in the form of situational awareness related to equipment per each predefined zone according to their availability status. Through an effective Human Machine Interface (HMI), the crew can easily identify zones and compartments affected and the status of equipment in the affected areas. This situational awareness capability identifies risks to survivability and allows in-time formulation of Damage Attack strategies. The equipment concerned can be related to the Ship Chilled Water System or Fire Main or auxiliary equipment critical to Damage Control and other mission critical systems.

Other IPMS BDCS survivability related functions include Propulsion system, Electrical system and Fuel system survivability awareness functions.

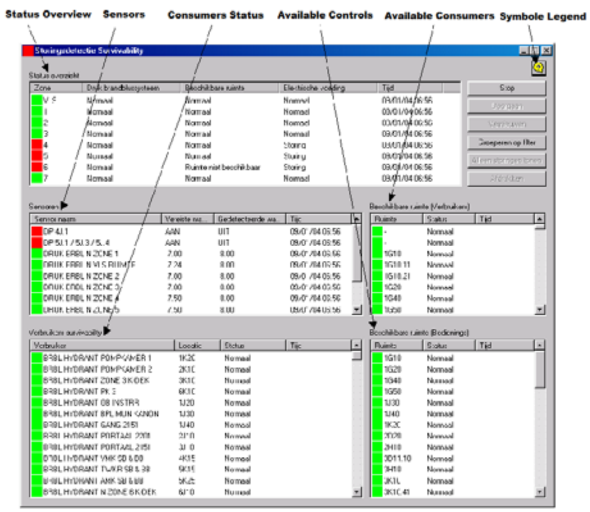

Figure 3: Typical BDCS Situational Awareness

In recent years variations of Autonomic Fire Suppression Systems (AFSS) have been studied and deployed to improve ship survivability under fire damage incidents. An independent AFSS ensures continued operation of surviving sensors related to the fire suppression agents in the event that the IPMS equipment is affected by an incident or in combat. During normal operations, the main IPMS control system performs the desired monitoring and control of the AFSS related equipment. In the event that the IPMS network or main control system hardware are damaged, a dedicated independent system (hardware/software) can assume activation and execution of the fire suppression system.

The BDCS features include a Crew and Equipment Resource Tracking system. Damage Control related equipment such as portable fire extinguishers, as well as Damage Control personnel are tagged and their movements are tracked in real-time via the BDCS General Arrangement Plan (GAP).

Despite consideration and inclusion of the above and other initiatives to improve equipment, systems and crew survivability during an incident, it has been recognized that there is a need for faster Damage Assessment and more rapid systems recovery, particularly when vital fluid systems are damaged.

Recovering from fluid system damage can take so long that otherwise intact critical functions are lost due to the loss of the fluid system. For example, fire spread may not be prevented because the firemain is not recovered in time. Or, critical combat system equipment may shut down because cooling water is not restored in time. Equally, in a Cruise ship, there are a number of mission critical systems that can impact the safety and comfort of passengers, where fast detection and fast recoverability from the incident are highly desired.

The above has given rise to the design and deployment of effective hardware and software solutions to further improve surface ship and submarine survivability utilizing optimum damage identification and recoverability schemes. In the next section, technologies considered for an advanced Autonomic Control System (ACS) applicable to CSW, FMS and Fuel systems are presented. The L-3 MAPPS IPMS for a target program takes advantage of some the presented technologies.

3. AUTONOMIC CONTROL SYSTEM USING DEVICE LEVEL CONTROL TECHNOLOGIES

With the typical technology in warships in service today, it takes at least 20 minutes to recover from weapon hit damage to the ship's chilled water system. In the likely event that the expansion tank drains, it could take over 90 minutes to recover the system. Vital combat system and command, control and communications equipment may shut down only a few minutes after they lose cooling water. Consequently, damage to the chilled water system is likely to result in the loss of otherwise intact equipment that is vital to the ship's mission and self-defense. (see Figure 4).

The weapon damage also typically damages network communications in the area in which valves would need to communicate with a control system to isolate the chilled water system damage. Therefore, the chilled water system could not be restored by remote control or from a centralized control system. Similar impact on the FMS can have undesired consequences.

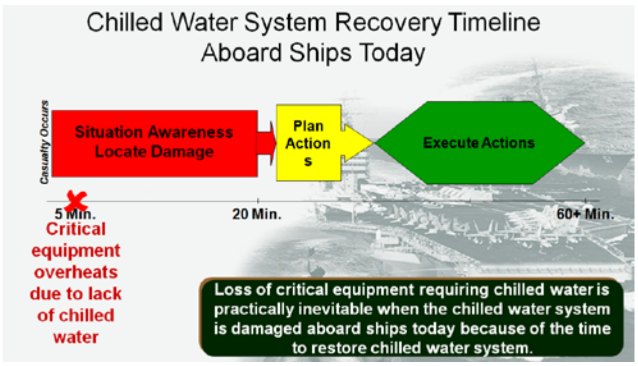

Figure 4: CWS Recovery Timeline

To overcome the above problem and in order to increase ship survivability, safety, security and operability, there is a need for the implementation of an advanced ACS utilizing Device Level Control (i.e. "Smart Valve") Technology. A valve that can recognize CWS/FMS/Fuel system ruptures and automatically close, without relying upon communications with other components or a centralized control system, enables rapid restoration of the above systems after a weapon hit. Such Device Level Control enables the component to make an effective control decision with communicating with any other device. MPR's patented hydraulic resistance / rupture path logic enables a "Smart Valve" to automatically detect and isolate fluid system ruptures without communicating with any other valves, sensors beyond the valve itself or a centralized control system. The "smart valve" is a typical motor operated valve with the addition of two pressure transducers, control logic hardware and software, and a network communications interface to allow the crew to control the valve remotely if desired and to enable situation awareness.

In addition to simply identifying and isolating ruptures, the Smart Valve can be programmed to automatically shift vital loads from normal to alternate CWS supply and to perform other functions related to control and alignment of the system, without depending upon communications with other components in the system.

The ship's FMS has an unlimited supply of water from the sea. The CWS, on the other hand, has only the water in the expansion tank for near-term replenishment of the system. Once the chilled water expansion tank is drained, recovery of the system takes a long time. An advanced ACS is required to operate quickly (in the order of seconds compared to minutes for the firemain) to isolate ruptures and prevent loss of water in the expansion tank.

Deploying separate control system hardware/software that is not integrated with other shipboard hardware does not necessary provide a survivable Autonomic Control System (ACS). The systems architecture must be designed so that surviving portions of the system can be recovered and vital services restored quickly after a damage event.

A modern ACS for a "standalone" CWS or FMS shall include capability for rupture detection (ie: identification), as well as capability for reconfiguration and fast recoverability from damaged conditions through appropriate manipulation of valves.

In collaboration with MPR Associates Inc, L-3 MAPPS is involved in the development and integration of the appropriate logic and algorithms required for the implementation of an advanced Autonomic Control Systems for the CWS, FMS and Fuel system on a target Naval Program. The experience extends to the automated valve performance requirements definition and associated system survivability analyses for the FMS and CWS.

In collaboration with Score (Eastern Canada) Limited, L-3 MAPPS has identified suitable valve/actuator hardware that will be complemented with L-3 MAPPS designed hardware to deploy advanced Smart Valve Technology for the desired ACS schemes.

The following discussion outlines the requirements for the smart valve/actuator and a unique approach for developing the fluid system rupture detection, isolation and reconfiguration automation logic based on over a decade of experience with the subject.

3.1. VALVES AND ACTUATORS SELECTION & MATERIAL

The implementation of the ACS complements the conventional AFSS and the overall survivability of a mission critical vessel, and requires careful consideration for selection of the most appropriate valve/actuators equipped with intelligent software and augmented with special hardware that can enable autonomic (device level) decisions and control actions.

The device level control has to be integrated with the main IPMS in order to allow the IPMS to perform normal control and monitoring functions while the IPMS hardware remains intact under normal and damaged conditions. When the IPMS data communication network or IPMS control for target subsystem (CWS, FMS etc) is lost, the autonomous agents will take control to identify leakages, to reconfigure the concerned plant and to recover from the incident in as fast as possible. Or, depending on the system performance requirements, the device level controls may provide the initial reaction to system damage, with the IPMS providing backup and enabling operator situation awareness.

For naval service, components in critical systems typically are required to pass a variety of stressing qualification tests, including: shock, vibration, submergence, life cycle testing, environmental temperature exposure, electromagnetic interference, and more.

3.1.1. VALVES

The selection of valves and actuators for Marine applications has seen some significant advances in recent years and this paper outlines how valve and actuator selection has been changed by advances in new technology. Some background on valves and actuator selection, materials and the principles of an “intelligent” valve are addressed below.

The size of the valve is obviously dictated by the size of the pipe work which in turn is dictated by the system flow rate requirements, allowable pressure drops and for sea water systems such as the fire main the fluid velocity must also be taken into account.

The type of valve used depends on the desired function, space envelope allowed and the allowable pressure drop. For example for isolation applications a butterfly valve will give the smallest space envelope and operating torque requirements but a much higher pressure drop than the same size ball valve. The ball valve however requires significantly more space and a larger operating torque meaning a larger actuator. Triple Offset Torque Seated (TOTS) valves are the latest development in butterfly valves and require little space, while demonstrating a higher level of leak-free performance in service.

Non return valves also present a wide variety of choice. There are swing check designs, piston, diaphragm, split disc and wafer poppet to name just a few.

Acceptable smart valve performance has been demonstrated with a variety of the types of valves common in shipboard fluid systems.

As with all valve designs for a specific application the most suitable style will depend on the valve size, allowable pressure drop and space envelope considerations. The specific material selected for a valve will depend on the service conditions and the system the valve will be fitted to.

The fluid passing through the valve dictates material choices. For a fire main or chilled water system a body material of nickel aluminum bronze can be acceptable. However the trim components would be different. A chilled water system can accept a typical 316 grade of stainless steel.

The presence of salt in the sea water systems will cause pitting or crevice corrosion in the usual grades of stainless steel. Seawater systems therefore use either monel (a copper nickel alloy) or a grade of stainless steel with at least 6% molybdenum.

However for chilled water systems a 316 grade of stainless steel is considered the ideal solution for trim components.

Composite technologies now offer interesting alternatives. There are manufacturers who have developed composite ball and butterfly valves for Naval applications. They are 25% lighter than the same steel valve and offer much better corrosion resistance particularly in sea water applications.

However there are disadvantages; one being that they have to be lagged in order to pass a fire test.

3.1.2. ACTUATORS

The survivability capability of most Naval vessels, including some mission critical Commercial vessels, is affected because shipbuilders mainly consider the deployment of manual valves rather than remotely controllable valves equipped with appropriate actuator/electronics.

It is common to find that the Ship owners/Navies also have limited input to critical design specifications for inclusion of advanced survivability enabled features. That allows the shipbuilders to pay less due consideration to survivability enabled technologies that could best serve target ships operations, safety, security and recoverability from damage incidents.

Electric actuation has only recently come to the fore. Initially large hydraulically or pneumatically powered actuators were used which gave size problems and also meant running air or hydraulic pipelines throughout the ship. However developments in the 1970's and 1980's led to the possibility of using compact electric actuators that had sufficient torque output to drive even the largest of valves used on warships.

The main advantages of electric actuation are:

- They are more compact than pneumatic or hydraulic alternatives which are vulnerable and a maintenance burden
- Used in conjunction with an IPMS system means reduced manning
- They can feedback valve position and movement
- They can feedback on valve performance

For Naval vessels, where specified, the actuators and/or valve/actuator unit shall be qualified for shock and vibration, EMI/EMC and noise.

All actuators provide local position indication, a manual override facility and interface seamlessly with many digital control systems. This is achieved simply and cost effectively by installing the appropriate circuit board module inside the actuators electrical housing. This is normally carried out at the time of production, but can be carried out retrospectively in the field should upgrades be found necessary.

Some actuators are equipped with IR setting tools that enables rapid and accurate commissioning of the actuator without the need to remove electrical covers. The speed of operation can be adjusted to provide hydraulic and surge protection.

Furthermore, an onboard data logger allows IR download of historical actuator/valve performance data, and communicates data that can be interrogated to determine accurate maintenance requirements. The data can include valve torque, actuator events and statistics. (see Figure 5).

As a result, the valve position, its movement and the general "health" of the valve can also be monitored remotely using a serial/intelligent interface. The fully integrated L-3 MAPPS On-Board Condition Based Maintenance (O-CBM) is capable of performing the required health checks for valves, actuators and related electronics.

Marine grade of Aluminum (LM25) is suitable for use in a marine environment. This material has also demonstrated its suitability to withstand impact through both the shock test and through the many hundreds of thousands of actuators installed in many different environments.

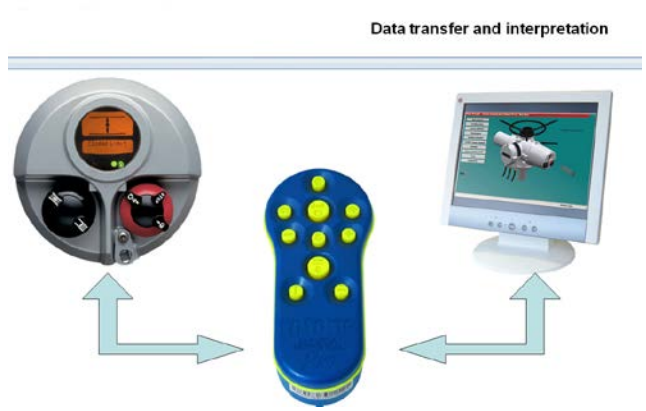

Figure 5: Date Collection & Transfer

3.1.3. SMART VALVES

Smart valves automatically isolate large leaks or ruptures to minimize the consequences of piping failures. This rapid isolation reduces the hazards resulting from fluid loss, reduces the cost of lost fluid, and can enable the continued operation of the intact portions of the fluid system. It can be applied to all mission critical systems onboard Naval surface ships and submarines, as well as on Commercial Cruise ships, FSO/FPSOs, LNGs and other desired vessels. It also has application in Oil/Gas/Water industries.

Aboard Navy ships, rapid isolation of damage to the chilled water system is essential to keeping vital mission systems functioning. Manual isolation of damaged fluid systems is time consuming because of the extent and complexity of the chilled water and firemain systems. The US Navy has installed Smart Valves in the chilled water system of new DDG 51 Class ships to ensure that chilled water cooling is maintained to vital systems after damage to the ship**.**

Combined with a supervisory control system (IPMS), the sensors in Smart Valves provide extensive information about the operating conditions in the fluid system. This information can be used in normal, day-to-day operations to optimize system performance and system maintenance. In addition, integrating the device level controls in the Smart Valves with supervisory level controls provides a very robust, flexible control system.

3.1.3.1. SMART VALVES FEATURES

A Smart Valve can make use of all the basic electric actuator features plus where applicable by actuator type:

- **Valve position:**
  - ➢ Open (100%)
  - ➢ Closed (0%)
  - ➢ Intermediate: (1 -99%)
- **Status:**
  - ➢ Opening
  - ➢ Closing
  - ➢ Moving
  - ➢ Local stop selected
  - ➢ Local selected
  - ➢ Remote selected
  - ➢ Open or close interlock active
  - ➢ ESD active
- **Valve alarms:**
  - ➢ Motor tripped on torque going open
  - ➢ Motor tripped on torque going closed
  - ➢ Pre-set torque exceeded
  - ➢ Valve jammed
  - ➢ Actuator being opened by hand wheel
- **Actuator alarms:**
  - ➢ 24v DC (120V AV) supply lost
  - ➢ Battery low
  - ➢ Internal failure detected
  - ➢ Thermostat tripped

A Smart Valve differs from conventional remotely controllable valves due to some special features:

- **Rupture detection –** Detection of a rupture downstream of the valve within a few seconds of the rupture event.
- **Customizable -** Can customize post-rupture response based on fluid system recoverability performance requirements. Smart Valve approach can be implemented on any size of valve. Smart Valve is drop-in replacement for standard valve sizes.
- **Independent -** Rupture detection and rupture response is independent of network communication between Smart Valves or between Smart Valves and central control station (IPMS).
- **Additional Data -** Smart Valve provides continuous real-time pressure and flow data to a network or central control station (IPMS). Smart Valves can provide condition based feedback on valve performance.
- **Self-contained -** Smart Valve is self-contained package requiring one communication cable and one power cable for valve control, valve information and sensor information.
- **Logic Card** – Executes Smart Valve Rupture Detection and Recovery software logic. The above can also be installed in the vicinity of the Valve/Actuator unit or within the actuator itself.

In addition to improved survivability, the pressure and flow information from the smart valves enables a comprehensive understanding of the fluid system under normal conditions. A typical smart valve configuration is illustrated below (see Figure 6).

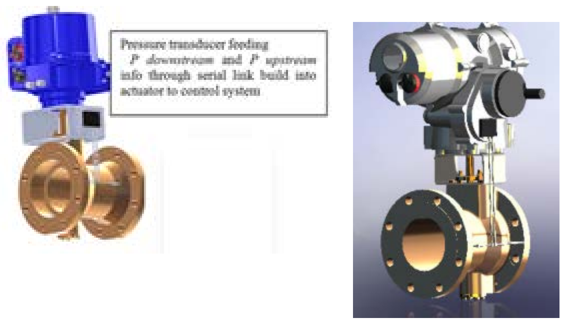

Figure 6: Typical Smart Valve Configuration

In the event of a failure of the downstream system for example the pipe work being ruptured due to battle damage, the measured pressure and flow characteristics would deviate from expected conditions, and in a very basic implementation, the network link will signal this to the IPMS or a standalone control system; which in turns orders the valve to shut thus preventing any further loss of the service fluid. The above does not include special intelligence at valve level.

However, an ACS Smart Valve shall be equipped with two pressure sensors and a specially designed electronic card that will be installed as an integral part of the Actuator assembly (or in a separate enclosure adjacent to the valve), to include the rupture detection and recovery software algorithm. The software logic will perform Real-Time analysis to identify a rupture, to isolate the problem through reconfiguration and to achieve recovery in the most optimum manner. The Smart Valve operation will be coordinated with the IPMS control systems through appropriate arbitration.

The Smart Valve data logger provides valuable input for the L-3 MAPPS Onboard Condition Based Maintenance (O-CBM) (see Figure 7).

The selection of the valve is a function of the pipes diameters in the main combined with pressure drop requirements and piping configuration. In collaboration with Score, TOTS valves have been identified as a suitable candidate for many applications. A typical configuration can include selected number of Smart Valves suitable for CWS 8” and 4” pipes (main and drop pipes) for pressure below 200 psi where fluid is defined as fresh water and, for FMS 8” and 6” pipes for pressure below 250 psi where the fluid is defined as salt water.

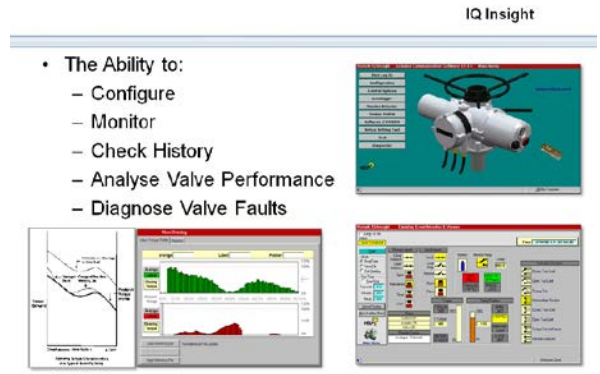

Figure 7: Interaction with O-CBM

A TOTS valve with a long pattern will enable the inclusion of two (2) pressure taps to be taken; one from upstream of the valve seat and one from downstream of valve seat. The selected electric actuator for all valves can be based on COTS. The COTS material for all valves can be based on Nickel Aluminum Bronze BS EN 1982 CC333G.

The above would allow for interchangeability of the 8” valve spares and valve assembly on both CWS and FMS should the need arise and, will reduce the cost of pipe modifications/adaptations that may have been required to accommodate Super Duplex 8” and 6” valves within the FMS.

3.2. ACS ALGORITHM

In collaboration with MPR, L-3 MAPPS is involved in the development of appropriate algorithms for the implementation of an advanced Autonomic Control System using Smart Valve Technology. The following discussion outlines unique approach for developing the fluid system rupture detection, isolation and reconfiguration automation logic based on over a decade of experience with the subject.

The development starts with the definition of performance requirements for fluid system recovery. Requirements address such features as how quickly the system must recover from damage to prevent damage from cascading into intact systems, and requirements to automatically reconfigure the system in addition to isolating ruptures.

The end user's requirements must be reviewed with the concerned shipyard before and after contract award, and shall be refined to ensure clear, common understanding of the requirements. Where the requirements are not clearly provided by the end user or the shipyard, recommendations will be proposed. During the software development process, the requirements shall be tracked to verify that all requirements are met.

The survivability performance of the automated recovery, the valve control logic and the architecture of the physical fluid system all are closely interrelated. For example, the size of the chilled water system expansion tank is a key factor in the successful recovery of the chilled water system. The piping architecture (separation and redundancy, the locations of valves, the locations of vital loads, etc.) also has a strong influence on survivability performance. Consequently, the survivability performance of the automated valves may be constrained or limited by the architecture of the fluid system.

Depending on the approach to the ship design and the specification requirements, it may be required to analyze the survivability performance of the overall ship in order to make recommendations related to the fluid system architecture in order to improve the ship's overall survivability performance. This could then assist the shipyard and the end-user with appropriate modifications for repeat or new build vessels.

Developing the fluid system rupture detection, isolation and reconfiguration logic requires a rigorous design approach which ensures the valve control logic meets the automated casualty response requirements without disrupting the day-to-day system operations considering normal operation, off-normal-intact operation, and casualty conditions other than physical damage to the piping. Achieving the foregoing objective requires rigorous, high-fidelity, hydraulic analyses of normal, off-normal and rupture conditions.

Appropriate software test environment in the form of simulations shall be developed to effectively represent the high-fidelity hydraulic model with the fluid system rupture detection logic. The computer based simulator looks at normal system transients associated with system fluctuations to ensure the system logic does not respond intact conditions. The above will look at off-normal non-rupture conditions such as pump trips or valve misalignments to ensure the system logic does not respond. It also looks at a wide array of ruptures of various sizes and in various locations throughout the ship to ensure the system logic correctly identifies and responds to the rupture.

The objective is to automatically and reliably detect and recover from a casualty while operating without false alarms or false actuations during normal and off-normal-intact conditions of the system. This cannot be achieved with an "off the shelf," predefined valve control logic!

For effective survivability performance, the control logic must be unique to the characteristics of each fluid system and the survivability performance requirements of each ship. For a typical ship design process, this requires an initial system hydraulic analysis, periodic reviews of the evolving fluid system design, and periodic updates of the hydraulic analysis to ensure the fluid system rupture detection, isolation and reconfiguration software meets the system performance objectives for each of the fluid systems as the designs mature.

3.2.1. DEVELOPMENT APPROACH

The high fidelity hydraulic model of the fluid system is integrated with prototype rupture detection, isolation and realignment logic. Here, the interaction between the system and the logic can be tested prior to hardware implementation. The stability of the logic and the fluid system model ensures proper response to normal, off-normal and casualty conditions. Multiple scenarios can be tested and the logic refined ensuring a reliable system and smooth transition to the ship.

The control logic consists of rupture detection, isolation, and reconfiguration modules available for the target vessel. Novel approaches and improved performance can be developed based on the target vessel's unique system performance objectives and lessons learned from the extensive testing done during computer simulations.

3.2.1.1. RUPTURE DETECTION LOGIC

The rupture detection logic developed by MPR for the CWS is proven rupture detection algorithm and is considered in L-3 MAPPS implementation. The MPR Patented Hydraulic Resistance Logic (US Patent 6535827) has proven to be a reliable and robust rupture detection methodology for CWS and firemain and has passed successful, full-scale live-fire weapon effects tests on a target USN vessel. These programs demonstrate hydraulic resistance logic is the superior rupture detection approach for both closed loop systems such as chilled water and open loop systems such as firemain.

3.2.1.2. RUPTURE ISOLATION LOGIC

The rupture isolation logic developed by MPR for the CWS is a proven rupture isolation algorithm for the fluid systems. The logic involves securing a predefined segment or zone of a fluid system when a rupture is detected anywhere in the segment or zone. This approach provides the quickest isolation response, minimizing fluid system losses at the expense of initially isolating more of the fluid system than necessary, requiring a subsequent reconfiguration step.

The firemain rupture isolation logic developed by MPR for the Smart Valves is another rupture isolation approach available for the fluid systems. The logic involves securing valves immediately bounding the rupture location. This approach results in the most efficient isolation securing the smallest piping segment required to stop the rupture. This approach takes longer to isolate than the CWS approach discussed above, but does not require the additional reconfiguration step as in CWS because the rupture is isolated at the location immediately bounding the rupture; the most efficient rupture isolation.

Successful automated fluid systems using both approaches have already been developed and tested. A hybrid of both approaches for the firemain and chilled water systems can also be deployed. Conversely, a target vessel could employ different rupture isolation approaches for the firemain and chilled water systems because they have different functional objectives and system performance requirements.

The optimum isolation solution for the firemain and chilled water systems must take into consideration the performance requirements, normal, off-normal and rupture conditions for both systems, and how these systems interact with other ship systems and the crew.

3.2.1.3. REALIGNMENT LOGIC

Realignment ensures the critical loads remain operational during a casualty. As an example for CWS the above is achieved by shifting chilled water supply from the current, damaged supply to a redundant, alternate supply source. Realignment logic would apply only if the fluid system architecture provides redundant, survivable, normal and alternate supply to critical loads.

3.2.1.4. RECONFIGURATION LOGIC

Depending on the rupture isolation logic used, reconfiguration may or may not be necessary. If the firemain approach is used, only the ruptured pipe segment would be isolated and reconfiguration is not necessary.

If the CWS approach is used, all pipe segments in the ruptured loop are isolated initially and reconfiguration is needed to restore flow the intact pipe segments.

The required deployment is a function of the user specification requirements.

4. ACS IMPLEMENTATION BENEFITS

In a ship (Commercial or Naval) equipped with extensive pipes and valves, the piping involves various deck levels, and therefore it is very difficult to identify the location of rupture as a result of damage to piping.

Furthermore, testing and experience demonstrates that when a ship suffers damage to the chilled water system as an example, it can take 90 minutes or more to restore the chilled water system. Vital combat system and command, control and communications equipment, on the other hand, may shut down within a few minutes after cooling water is lost, seriously impairing the ship’s mission and self-defense capabilities. Similarly, FMS, Fuel system and other vital ship subsystems can lose valuable or hazardous resources by the time the crew identify and restore systems.

With a smart valve system, the chilled water and other desired systems can be restored automatically (on the order of approximately 90 seconds) in sufficient time to keep intact mission equipment operating.

Together with the implementation of an advanced ACS logic, to include rupture detection, rupture isolations, realignment and reconfiguration, the ship survivability can be effectively improved. Vital combat and communication related equipment as well as damage and ship fuel system equipment and resources can remain operational and/or restored in an optimum manner.

To start with, the implementation of the ACS requires detailed specifications from the End Users and design consideration by the concerned shipyard. Next, there is a need for closer collaboration between the End User, Shipyard and the Control System Supplier in validating the requirements against the basic ship designs and establishing the optimum number and location of the Smart Valves in the concerned Main and Drop pipes to best achieve the desired performance and recovery objectives. The above can include computer based simulations to study performance of the system under various damage conditions.

5. CONCLUSION

This paper presented a comprehensive approach to the implementation of Autonomic Control System Scheme utilizing Smart Technologies as means for Survivability and situational awareness enabling technologies.

The above can be an enabler of manning reductions onboard the target vessels, will reduce operations burden on ship crew during incidents and systems recovery, improves safety of equipment and better ensures operability of vital ship systems; such as Combat and Communication systems

Various configurations can be adopted; including the implementation of the ACS Logic in the main IPMS, while allowing the IPMS main hardware to execute the command and control functions when a rupture is detected, or by deploying the software in a separate dedicated control system consisting of dedicated LOPs and DAUs in order to increase autonomy level, or in its most complete form to combine the high level IPMS control systems with the adoption of Smart Valve technologies.

The deployment of the ACS is not limited to critical Combat ships. It can be deployed on mission critical Commercial ships such as Cruise ships, LNGS and, utilized in Water/GAS/Oil/Electric utilities.

L-3 MAPPS will provide the required electronics Logic Card and the ACS Logic algorithm for installation in conventional valve/actuator assembly or in a close proximity to valve/actuator assembly. The collaborative effort between Score (Eastern Canada) Limited for selection of the most appropriate valve/actuator assembly, and with MPR Associates Inc will ensure provision of proven technologies. The proposed approach, in part is being deployed by L-3 MAPPS on a target ship at present.

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BIOGRAPHY

Dr. Reza Shafiepour holds a BSc in Electrical Engineering, Master degree in Power Transmission and Distribution, and PhD in Power Systems Control & Monitoring from the UK. His expertise in Control Systems is as a result of working at Industrial Companies in the UK and Canada; including Westinghouse Systems Ltd (Schneider), National Grid Company and CAE Inc. Dr Shafiepour has had various involvement with the implementation of Energy Management and SCADA Control Systems for a number of Power utilities worldwide, and since 1999 he has been contributing to the evolution of the

L-3 Communications MAPPS Inc IPMS and BDCS Products. He is currently a Regional Director of Marketing at L-3 MAPPS in Canada.

Eric Runnerstrom is senior associate at MPR Associates and holds degrees in Naval Architecture, Marine Engineering, and Ocean Engineering. Mr. Runnerstrom has performed R&D to improve firefighting doctrine and to demonstrate technology for damage control with reduced manning. The "smart valve" technology, for which Mr. Runnerstrom is a holder of U.S. Patent 6,535,827, is a product of one of those R&D programs. Mr. Runnerstrom also supported the Program Executive Office for the DDG1000 acquisition in the areas of human systems integration and damage control. He had a key role in the design of the automated recovery capabilities for the DDG1000 fluid systems. Prior to MPR, Mr. Runnerstrom was an engineering duty officer in the US Navy and developed the Navy's deactivation diagram-damage tolerance methodology for assessing the survivability of distributed ship systems.

Ryan Downs is the Vice President of Federal Services of MPR Associates and holds a BSc in Mechanical Engineering. Mr. Downs has 15 years experience in Navy damage control and autonomous control system design, including the design and development of the USN DDG51 Chilled Water Automation System (CWAS), concept design for DDG1000 AFSS and functional prototype of the Damage Control Automation for Reduced Manning (DC-ARM). Mr. Downs holds Patent 6,535,827 for the Smart Valve rupture detection and isolation logic. He is currently leading defense, energy and security business activities for MPR Associates.

Gilbert Whyte is the Operations Manager for Score (Eastern Canada) Limited's and heads up their Halifax, NS operation. He has over 20 years general management experience, with last 15 years in Logistics and Global Valve Supply Chain. Gilbert has a MBA from the Open University with focus on Global Supply Chain.

Geoff Pearson is the Engineering Director for Score Marine Ltd, part of the Score Group of companies and is based at their headquarters in Scotland. Geoff has over 30 years experience of valve and actuator design for the UK Royal Navy, Indian, US, Australian, German, Swedish and Norwegian Navies, having previously been the Engineering Director at Hale Hamilton for 12 years before joining Score. Geoff currently is overseeing the valve and actuator design and procurement for the UK's QEC Carrier programme as well as providing support to the UK Royal Navy as Technical Authority for all valve related activities. Geoff holds a BSc Hons in Mechanical Engineering.