Design And Implementation of a PLC-and-HMI-Based Watertight Door Control System Prototype On a Self Elevating Platform Vessel

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Abstract — Safety compartments on a ship type self-elevating platform very depends on performance watertight door inside prevent water seepage in conditions emergency. Operation door manually or semi - automatically on some ship units Still leaving gap in the form of slowness time responsiveness and lack of supervision centralized, so that potential lower reliability system safety. Article This describe the design process get up A prototype controller automatic For watertight door which utilizes programmable logic controller (PLC) and human machine interface (HMI) as the core of control and monitoring . hardness used includes Siemens S7-1200 PLC, Omron NB7W HMI panel, stepper motor driven through TB6600 driver, as well as limit switch as detector position end door. Prototype This is also equipped feature warning early (alarm) and locking interlock so that the command control local and centralized No each other collide. Trial done on two scheme operation, namely control local through push button and control centralized through order central close on HMI, each repeated several times to evaluate consistency Work every function. Test results show that all over function start from motor movement, detection limit switch, activation alarm, until status display on HMI running in accordance design on each experiment. Centralized mode proven capable close all over sliding door in a way simultaneously at a time disable control local, while indicators on the HMI update the door status in a way direct and accurate. Prototype This show that PLC and HMI integration is feasible considered For increase reliability system safety watertight door in the environment boat.

Keyword: Watertight door, PLC, HMI, monitoring, alarm, interlock.

I. INTRODUCTION

Door watertight on the ship type self elevating platform (SEP) is one of the device safety that holds distribution of water between compartments so that Power buoyancy and stability boat still maintained. In some units that are still depend on manual or semi-automatic operation, time slow and minimal response supervision centralized become constraint alone, especially in conditions emergency that demands closing door in a way fast and simultaneous. Needs this is the basis the need system control fast, accurate, and automatic monitored from One point control.

Development automation industry show that combination Programmable Logic Controller (PLC), Human Machine Interface (HMI), and Supervisory Control and Data Acquisition (SCADA) are capable jack up performance monitoring and control in a way significant because the data can observed in a way real-time and visualized with more informative for operators [1]. Concept similar is also proven in the application monitoring based Integrated Internet of Things (IoT) with PLC and HMI, where supervision distance Far become more flexible without reduce speed response to change condition system [2]. On the side interface, the use of HMI is also reported capable replace method hazardous manual work error with appearance more control responsive and easy read operator [3], while PLC integration with technology modern data communications provide time short response and level high reliability in application scale industry [4].

Although various study previously has prove benefit PLC and HMI integration on various application industry, the application of which is special discuss door watertight on the ship type self elevating platform (SEP) still seldom found in literature, especially that which combines scheme control two modes (local and centralized) at once with mechanism interlock intermode in One complete prototype. Most of it study previously tend focus on one aspect just, for example monitoring distance Far IoT based or control motor speed, without present combination control, monitoring, and mechanisms security (alarms and interlocks) integrated research This make an effort fill in gap the with present a prototype that integrates third function the at once, so that expected can become reference beginning for development system similar to the SEP ship in larger scale big.

Based on provision International Maritime Organization (IMO) in Safety of Life at Sea (SOLAS), watertight door mandatory equipped status indicator, system alarms and interlocks to prevent errors dangerous operations crew boat can prevented [5]. Implementation draft the seen in the design system control door watertight ship passengers who combine two PLCs and HMI panels via network data communication for use fulfil provision status indicators and alarms according to SOLAS [6]. For fulfil provision said, PLC many chosen as controller Because Work based on cycle deterministic scan — reading input, execute logic, then renew output so that replace series relay conventional with more systems flexible and easy maintained [7]. One of the common series used For scale small until medium is the Siemens S7-1200, which provides digital-analog input/output as well communication Ethernet For needs integration with HMI [8].

the device level field, position end door detected through limit switch that changes NO/NC contact when the lever pressured by movement door, while driving force door utilise moving stepper motor based on amount credit so that his position can arranged in a way precision [9], [10]. Reliability system furthermore supported by mechanisms alarm that gives warning moment condition deviate from point safe [11], as well as monitoring HMI based displaying operating parameters in a way real-time through network Etherne [12]. Need will system as reliable as This the more relevant remember study incident on the Self Elevating Platform show risk operational that is not small, good at stage transit, installation, and when operating on site [13], so that integrity compartment through door reliable waterproofing be one of point critical safety boat type This .

Reviewed from side architecture control, modern PLCs such as the Siemens S7-1200 are basically operate three stage repeated in every cycle scan, namely reading all input status to in image memory, execution of the logic program that has been arranged (generally in form ladder diagram), and updates all output status at the same time at the end cycle [7]. Mechanism This make behavior system become deterministic and easy explored, different with series relay conventional changes the logic demand changes wiring physical. In addition, support communication Ethernet The built-in features on the S7-1200 make things easier data exchange with HMI device without need module communication additionally, so that cost and complexity development system can pressed [8]Pulse Train Output (PTO) feature available on the series this is also one of the consideration main his election, because allows the PLC to control stepper motors automatically direct without module control movement separated .

On the side operator interface, HMI plays a role as visual bridge that translates process data into appearance informative graphics, so that operators can monitor door status and pick up decision without must do inspection physique direct to field [3]. Concept This in line with principle Common Supervisory Control and Data Acquisition (SCADA) applied on a scale industry more large , where the HMI functions as point control and supervision centralized connected with many PLCs or remote terminal unit at a time [1], [12]. On the prototype scale small as discussed in article this, the same principle implemented in a way simple through one connected Omron NB7W-TW01B HMI unit direct with one PLC, but still accommodate need base supervision centralized in the form of status indicators, alarms, and commands central close that can reach all over door at a time.

From the side actuato, the selection of a stepper motor is based on its moving characteristics based on amount credit discrete, so that position Finally can predicted in a way precision without require a feed sensor come back complicated position [8]. Precision of movement This participate determined by configuration driver, where the settings more microsteps tall produce resolution more movement fine with consequence reduction in available peak torque, so that the election need consider burden mechanical current from movable door [10]. Approach control speed based method start - stop applied in other studies also become reference so that the movement of the motorbike does not cause jolt mechanical that can speed up wear and tear component [10]. Meanwhile that, existence limit switch on both end track door functioning as reference position absolute corrective potential accumulation possible error (drift) arise from control based credit solel.

Aspect safety participate supported by the system alarm that gives warning early moment condition deviate from point safe, as common applied to various system protection automatic based control distance Far [11]. In the context watertight door, condition deviate the represented by position the door is between fully open and fully close status, which means compartment Not yet fully waterproof. In addition to the alarm, the mechanism interlock participate added For prevent conflict order between control local and control centralized, a needs that become the more crucial remember study incident operational on SEP shows that error procedures and failures coordination often become reason significant from incidents that occur, both at the stage transit, installation (jacking), as well as moment operating on site [13]. Principles locking cross kind of This in line with prototype door interlock system based contactor designed electricity For ensure only One door that can open on one time, which is in the test proven Work in a way stable and reliable in prevent condition No safe [14]. With Thus, the combination between control automatic, supervision centralized HMI- based, as well as interlocking alarm and interlock mechanisms complete become base design prototypes discussed in the section furthermore .

II. METHODOLOGY STUDY

A. Design System

Prototype built from four group interconnected components connected, namely the input unit (push button and limit switch), controller main in the form of a Siemens S7-1200 PLC, Omron NB7W-TW01B HMI interface, and actuator stepper motor. Relationship intercomponent the depicted in the block diagram of Figure 1.

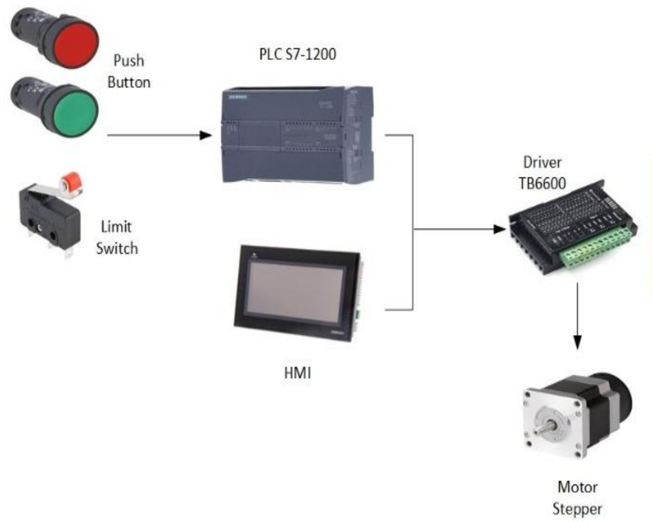

Figure 1. Block diagram system control watertight door

Signal from push button and limit switch enter to the PLC as input data that determines action Next. PLC is connected to HMI via network Ethernet so that data exchange takes place real-tim, whereas PLC output to stepper motor No connected in a way directly, but rather pass TB6600 driver that translates PLC pulse becomes motor rotation according to desired direction and spee.

B. Design Mechanical

Structure physique prototype consists of on the control panel made of transparent PVC 2 mm thick is selected Because light and easy observation components inside as well as two type door, namely sliding door on the side right and rear are moved stepper motor, and one hinged door on the side left as variation mechanism. Each sliding door equipped pair limit switch at the end the track as well as buzzer in the section on as marker when door currently moving. Design overall mechanical shown in Figure 2 and Figure 3.

As marked in Figure 2 and Figure 3, the frame main along with transparent PVC panels 2 mm thick forming a covering sheath two sliding door units (Sliding Door 1 on the side right and Sliding Door 2 on the side back) and one hinged door unit on the side left as variation mechanism openin. Control panel on the part front Contains a Siemens S7-1200 PLC with its I/O terminals, 24 VDC power supply, TB6600 motor driver, and Open/Close push button for operation local each door. Stepper motor that drives mechanism shift placed united with rails on each sliding door, while limit switches are installed at the fully open and fully close points of each door for give reference position to the PLC. The buzzer is placed on the part on sheath as audio indicator when door currently move.

C. Design Programming

Control program arranged in form ladder diagram use device TIA Portal software, with executed logic repetitive follow cycle PLC scan. The program flow is designed so that at each cycle, PLC reads the mode selector status (Local /Remote) first formerly before determine source the command to be executed. In Remote mode, control local disabled through logic interlock so that all over order only can given through Central Close button on the HMI, which will move all sliding doors close in a way simultaneously. In Local mode, control centralized disabled and operator controlled each door in a way independent via the Open/Close push button in the field. In both modes, the limit switch status remains monitored For determine when should the motorbike stopped as well as For evaluate alarm condition, which will active if position door is between fully open and fully closed status . Flowchart complete from logic the shown in Figure 4

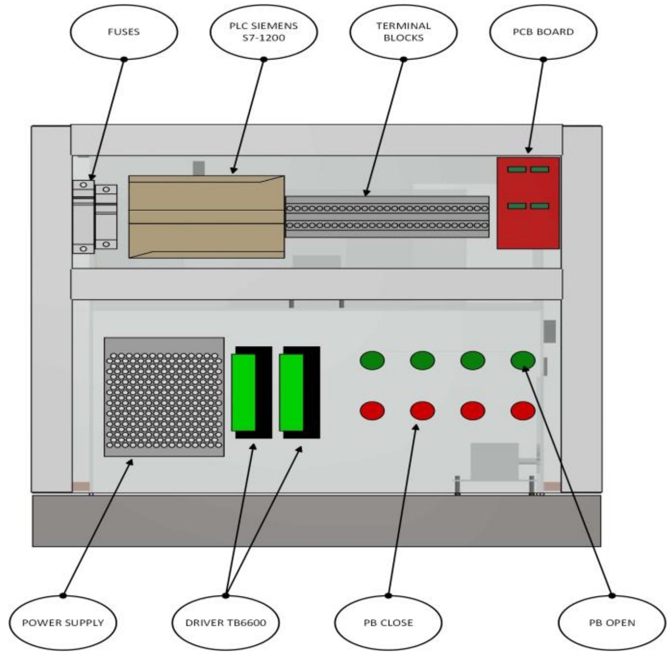

Figure 2. Design mechanical looks front

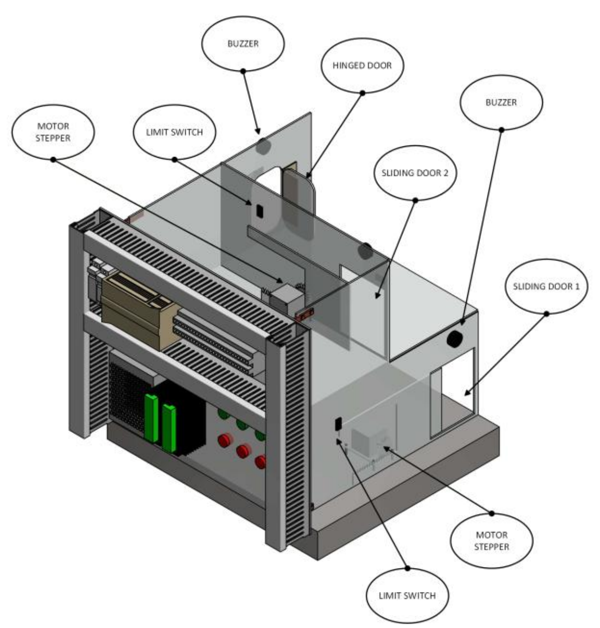

Figure 3. Design mechanical looks overall

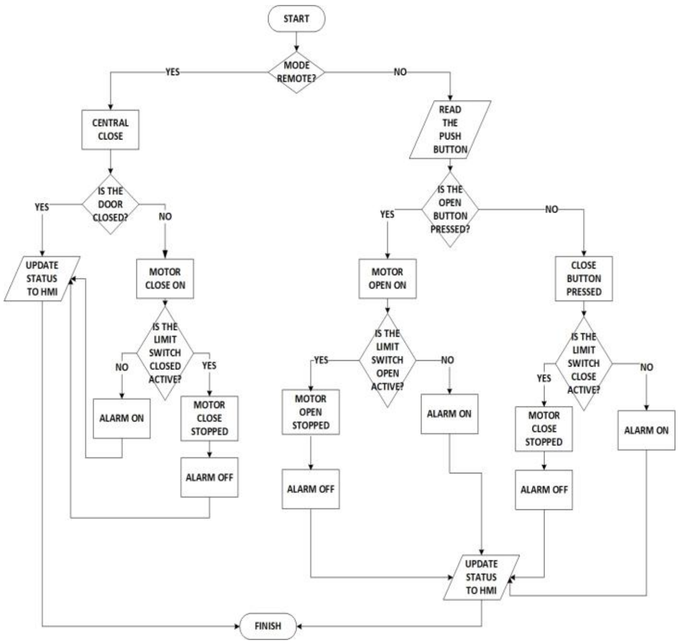

Figure 4. Design flowchart programming

D. Electrical Design

Series electrical supplied 24 VDC voltage that has been pass fuse as protection connection short before distributed to PLC, HMI, push buttons, and limit switches. PLC digital output utilizes feature Forwarded Pulse Train Output (PTO). to the PUL+ and DIR+ terminals on the TB6600 driver via series divider voltage become approximately 5 VDC according to need driver. Configuration microstep on driver set to position 32 (6400 pulses per rotation) via DIP switches S1–S3 as summarized in Table I, in order to get smooth motor movement without sacrificing torque excessive.

TABLE I. Configuration Microstep Driver TB6600 Used

Microstep	Pulse / Spin	S1	S2	S3
1	200	ON	ON	OFF
8	1600	OFF	ON	OFF
16	3200	OFF	OFF	ON
32*	6400*	OFF	OFF	OFF

* Configuration used in the prototype .

In addition to driving the motor, the PLC output also activates buzzer during the opening and closing process ongoing as marker that door currently operating, while communication towards full HMI utilise track Ethernet on the same 24 VDC supply with PLC.

E. Design HMI Interface

HMI display is designed use device NB-Designer software so that operators can understand condition system in a way at a glance. As seen in Figure 5, there is selector local mode selection or remote, two areas of representation door waterproo, as well as status and alarm indicators on each door. When remote mode activated, all the door is still open will close in a way automatic and control local disabled while, so that order from both modes do not each other collide.

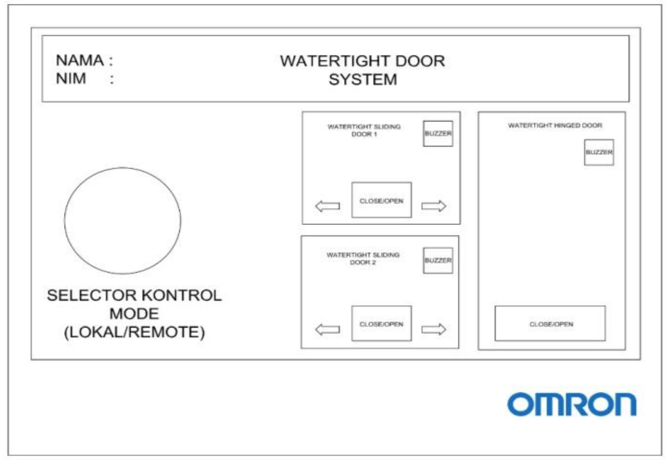

Figure 5. Design HMI interface

F. Procedure Testing

Testing done on four aspect function system, namely (1) control local through push button on each sliding door, (2) control centralized through order central close on HMI, (3) response alarm to position the door that doesn't fully open or closed, and (4) suitability appearance monitoring on HMI against condition current doo. Every scenario repeated several times to ensure consistency Work stepper motor, limit switch, and indicator system.

Testing done in a way directly on the prototype physical in the laboratory, with recording results done manually based on observation to HMI display and movement mechanical each door. Response time system participate observed in a way qualitative, namely difference between moment order given (good) via push button or central close) with when the motor starts move, to ensure that No there is significant delay in PLC program execution. Parameters recorded at each repetition covering condition beginning and end door, motor action that occurs, limit switch status, and alarm status, as well as summarized in Tables II to IV.

III. Results and Discussion

A. Testing Control Local

Testing control local ensure that knob open and close on each sliding door produce appropriate motor response. Summary results Testing on Sliding Door 1 is presented in Table II the pattern identical results were also obtained on Sliding Door 2.

TABLE II. Summary Testing Control Local (Sliding Door 1)

No	Knob	Initial Conditions	Motorcycle Action	Final Condition	Alarm
1	Open	Closed	Reverse	Fully open	OFF
2	Open	Closed	Reverse	Fully open	OFF
3	Close	Open	Forward	Fully close	OFF
4	Close	Open	Forward	Fully close	OFF

All over order knob the motor responds accordingly expected direction, and limit switches succeed stop movement right on target end without trigger alarm, so that control local can it is said Work reliable in conditions normal operation.

B. Testing Control Central Close

TABLE III. Summary Testing Control Centralized

No	Object	Initial Conditions	Action System	Control Local	Final Condition
1	Sliding Door 1	Open	Forward	Non-active	Fully close
2	Sliding Door 2	Open	Forward	Non-active	Fully close
3	Sliding Door 1	Closed	Silence	Non-active	Fully close
4	Sliding Door 2	Closed	Silence	Non-active	Fully close

Order central close from HMI successfully close all over the previous door open, while the door that has been closed keep quiet without movement additional. During this mode active, control local consistent be in condition inactive, which indicates that mechanism interlock walk in accordance design in prevent collision order.

C. Testing Alarm System

TABLE IV. Summary Testing Alarm System

No	Door	Initial Conditions	Order	Limit Switch Status	Alarm
1	Sliding Door 1	Closed	Open	Not yet detected	ON
2	Sliding Door 2	Closed	Open	Not yet detected	ON
3	Sliding Door 1	Open	Close	Not yet detected	ON
4	Sliding Door 2	Open	Close	Not yet detected	ON
5	Hinged Door	Closed	Open	Not yet detected	ON

Alarm in consistent active during door be in between position open full and closed full, then outage quick after limit switch detect position end. Special hinged door that only own One limit switch detector condition closed, alarm still light up during door open. Behavior This precisely in line with practice on board, where the doors type This ideally always is at in condition closed for safety.

D. HMI Monitoring Testing

Compliance between condition physique doors and displays on the HMI are tested with observe OPEN / CLOSE status change along with indicator alarm moment door move. HMI display when second sliding door be in position open, with status indicator changed become OPEN and box alarm at the corner right on each door blink when the sensor is not detect door.

Same pattern also applies on the contrary so door reach position closed perfect, the status on the HMI changes become CLOSE and indicators alarm off. On the hinged door, the status is OPEN accompanied by alarm light up appear during door open, and both back to normal when door closed. Compliance appearance this is all over test show that system monitoring capable reflect condition field in a way accurate and precise time, so that support taking operator decision without need checking physique direct.

TABLE V. Testing Monitoring System on HMI

No	Object	Activity	Tool Condition	Visual Indicators	Results
1	Sliding Door 1	Open door	Door move open	OPEN status	In accordance
2	Sliding Door 1	Close door	Door move close	Status CLOSE	In accordance
3	Sliding Door 2	Open door	Door move open	OPEN status	In accordance
4	Sliding Door 2	Close door	Door move close	Status CLOSE	In accordance
5	Hinged Door	Open door	Door open	OPEN status	In accordance
6	Hinged Door	Close door	Door closed	Status CLOSE	In accordance
7	Alarm	Buzzer active	The alarm sounds	Flashing alarm	In accordance

F. System Timing Chart Analysis

For clarify temporal relationship between signals input and output during One cycle operation door a timing chart is arranged as follows shown in Figure 6. This diagram represent behavior four signal main, namely push button, motor, limit switch, and alarm, against axis time t0 to t4. As seen in the diagram, when push button pressed at t0 (signal changed from low become high), motor and alarm in a way simultaneously follow changed become high (active), while signal limit switch still be in condition low no active) because door Not yet reach position end the track. Condition This endure up to t1, namely moment limit switch detect position end door and change become high (active) at the same time, the signal push button, motor, and alarm simultaneously return to condition low (inactive). Identical pattern repeated at interval t2–t3, which confirms that behavior system nature consistent and repetitive For every cycle operation.

Relationship patterns the show implementation logic seal-in (locking) self) which is common used in circuits PLC-based motor control, where the signal push button that triggers the motor and alarm active, while condition active the maintained until contact limit switch in position end cut off series locking as also applied to the design automation door PLC based which uses combination push button, motor, and limit switch For stop movement in a way automatic appropriate at the specified position [15]. In other words, limit switch functioning double, namely as reference position at a time as switch breaker that disables the motor and alarm in a way automatic without need intervention advanced from the operator, so that fixed motorcycle risk move pass limit safe (overtravel can avoided).

E. Discussion General

In a way overall, results testing show that PLC and HMI integration in prototype This capable operate function control, supervision and protection in a way coordinated, in line with findings in research previously emphasized superiority automation PLC based in matter determinism and speed response [1], [7]. The success of Remote mode in close all sliding doors in simultaneously through One Central Close orders also strengthen argument that centralization control can cut time responsive compared to manual operation in each point door in a way separate, as be one of motivation beginning study this. Consistency results on repetition testing participate indicates that combination of stepper motor and TB6600 driver used Enough reliable For application scale prototype, although Thus, the potential accumulation error position due to mechanical slip on the scale full still need anticipated through calibration repeat periodically against the limit switch.

A number of limitations participate identified during study taking place. First, testing done on prototype scale small with burden distant mechanics more light compared to actually watertight door, so motor torque characteristics and driver response under conditions burden full Not yet fully depicted. Second, testing Not yet covers scenario failure components (fault injection), such as limit switch failure or lost communication between PLC and HMI, which is important For evaluate resilience system in condition emergency indeed. Third, the prototype This Not yet tested under conditions environment maritime current like exposure vibration, humidity, and salinity the height that can influence reliability component electronic in term long. Third aspect the become direction relevant development For study advanced before system This considered For applied on a scale the real ship.

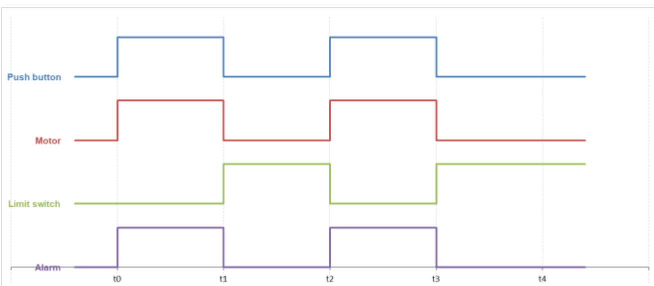

Figure 6. Timing chart of the relationship push button, motor, limit switch, and alarm

TABLE VI. Time Diagram t0-t4

Data	t0-t1	t1-t2	t2-t3	t3-t4	Description
Push button	ACTIVE	INACTIVE	ACTIVE	INACTIVE	Input from operator
Motor	ACTIVE	INACTIVE	ACTIVE	INACTIVE	Actuator output (motor)
Limit switch	INACTIVE	ACTIVE	INACTIVE	ACTIVE	Position feedback
Alarm	ACTIVE	INACTIVE	ACTIVE	INACTIVE	Status indicator

IV. Conclusion

Prototype system control door PLC and HMI based watertight door system built on research This proven capable operate three function mainly in a way integrate. Control automati, good through push button local and order central close on HMI, working in accordance design on each testing conducted. System monitoring HMI-based successful displays open-close status and conditions alarm in a way real-time, while mechanism alarms and interlocks proven effective prevent condition the door that doesn't safe at a time avoid conflict between order local and centralized. Third function those, control, monitoring, and security walk as One unity that improves reliability, safety, and efficiency operational door watertight on the ship self-elevating platform. Development advanced can directed towards the use of more position sensors precision like encoder, addition of barrier sensor with mechanism override emergency, features data logging For evaluation performance, integration with SCADA networks on a scale industry, as well as more HMI display interactive with notification condition emergency.

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