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Research Article

Relay Based Robot For Automated Isolating Systems Used In Steering Gear Of A Ship : Comparative Performance Analysis With Manual System

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Abstract—According to SOLAS, it is mandatory to provide all sailing vessels with an efficient main steering gear as well as an auxiliary steering gear. For turning the ship to the left (port side) or to the right (starboard side), while sailing, the steering gear is used. The requirement is that the main steering gear should be power operated except in the case of very small vessels/ships. The steering gear control system is the equipment by which helm orders/autopilot orders are transferred from the wheelhouse to the power units of the steering gear. The Steering Gear control system consists of the electrical wiring, electrical motors, hydraulic pumps, piping, receivers, transmitters, and control equipment. This paper focuses on relay based Robot for automated isolating Systems used in Steering Gear of a Ship and the comparison of the performance of a manual isolating system and Automatic Isolating system with robotic relay logic control. An experimental hardware prototype is designed and developed to compare the performance of steering gear isolating systems. The developed hardware is tested successfully and found that, it is better with respect to the following features.

- Fault Isolation time.
- Independent operation.
- Operation of steering gear in various healthy and faulty conditions.

Keywords— Steering Gear, Robotic isolating system, manual isolating system, SOLAS and auxiliary steering gear.

I. INTRODUCTION

According to Regulation 29 of Part C in Chapter II-1 pertaining to SOLAS – International Convention for the Safety of Life At Sea (Lloyd's Register Rulefinder 2014 – Version 9.22), it is mandatory for all the tankers exceeding 10,000 deadweight tons in gross tonnage to be designed capable of recovering their steering ability in 45 seconds after experiencing a single failure of part of the main steering gear power actuating system [1].
The fundamental controlling apparatus will contain either:
a) Two autonomous and separate force inciting frameworks, each fit for meeting the prerequisites [2] or
b) Possibly two indistinguishable force impelling frameworks which, acting at the same time in ordinary activity, will be equipped for meeting the necessities (of putting the rudder over from 35° on one side to 35° on the opposite side with the boat at its most profound seagoing draft and running ahead at greatest ahead help speed and, under similar conditions, from 35° on either side to 30° on the opposite side in not in excess of 28 s) [3]. Where important to conform to this prerequisite, interconnection of pressure driven force impelling frameworks will be given. Loss of pressure driven liquid from one framework will be fit for being recognized and the blemished framework consequently disconnected with the goal that the other impelling framework or frameworks will remain completely operational. [4]
To meet the SOLAS regulation, the automatic isolating system is designed as following: For a four ram's steering gear system with four pumps, the system has two hydraulic oil tanks with float level sensors. The first level sensor is called as Low level sensor and the second level sensor is called as two low level or low-low level sensor [5]. If there is oil leakage in the system, eventually, the float sensors will get activated one after the other. These inputs from the float sensors are used for automatically isolating the defective system which has the

leakage. At first, the manual isolating system is discussed here, then followed by the automatic isolating system and then a comparison is made between both the systems

A. Steering gear system with manual isolating system

One manual isolation valve is installed in the main hydraulic circuit connecting lines between the NO.1 and NO.2 Power Actuating System. If oil leakage takes place, and the tank level sensor detects it, which can raise an alarm, then the manual isolation valves and by-pass valve can be used to isolate the defective power actuating system so that emergency steering (using 2 cylinders)can be performed using the remaining healthy power actuating system.

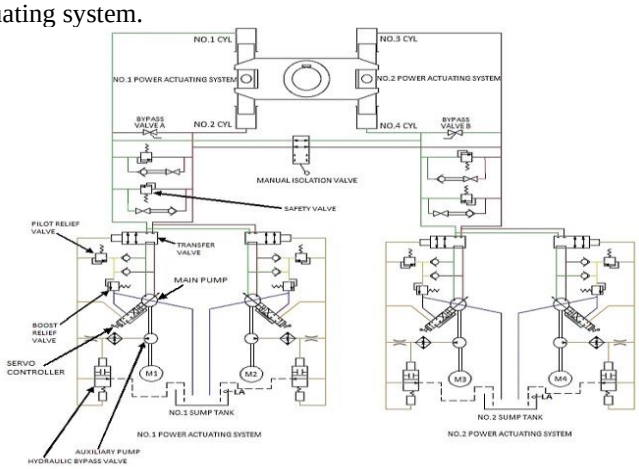


Figure 1.Steering gear system with Manual Isolating valves[6]

B. Steering gear system with automatic isolating system

Two Automatic isolating valves are installed in the main hydraulic circuit connecting lines between the NO.1 and NO.2 power actuating system. If there is oil leakage, and if the float sensor gets activated then that (On-Off) signal is used to isolate the faulty power actuating system which has the leakage, so that the steering gear system can still be operated with the healthy power actuating system. The faulty cylinders are also bypassed so that they don't cause any hydraulic locking. With this system the steering gear can be fully functional at all times. In case if the system malfunctions, it can also can be changed to manual mode so that faulty operation can be prevented. The circuit design is shown in Section 2.1 and the operation of the automatic isolating is system is explained in the section 2.2 Testing and Observation Table 1.

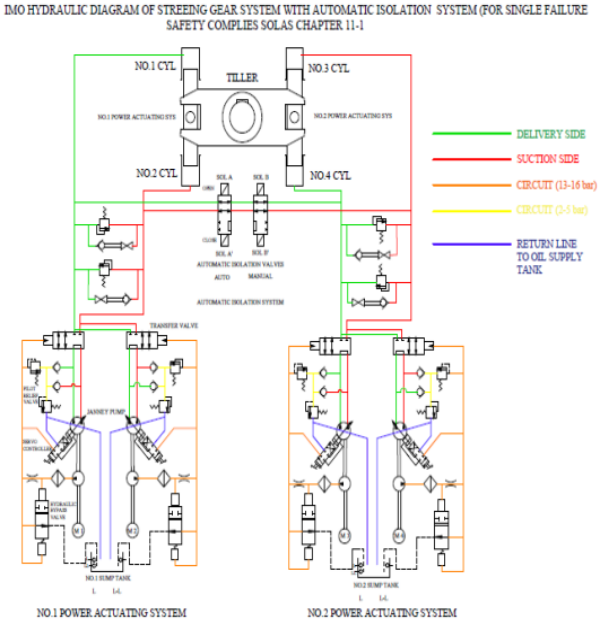


Figure 2. Steering gear system with Automatic Isolating valves [7]

II. DEVELOPED HARDWARE MODEL

A. Developed Model of steering gear starter panel

The starter is a DOL starter built using basic electrical equipment. The power supply for the starter is 440 V AC. This board contained starters for four steering gear motors. The start and stop push buttons which are used are NO (Normally open) type.

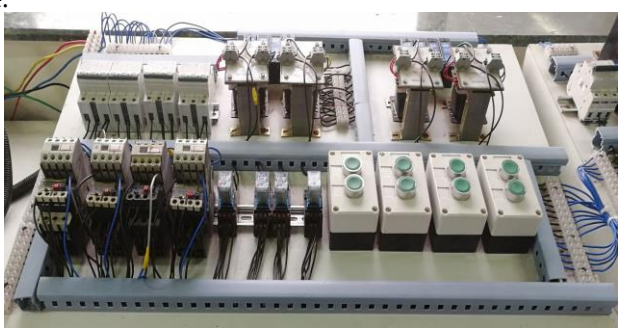


Figure 3. Developed Hardware Model of steering gear starter panel

B. Developed Model of control panel

The panel which does the isolation has fifty seven relays and basic electrical equipment. Upon receiving an input from the toggle switches (fitted in place of float sensors), the relay logic operation performs the isolation with the help of the steering gear motors starter panel.

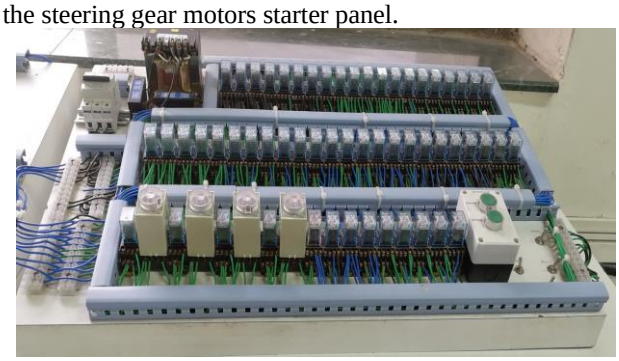


Figure 4. Developed Hardware Model of control panel

C. Developed LED Display Board

The Display board indicates the operation like motors (On/Off), isolation valves (Open/ Close), Tanks (Low/ Too-low), etc. The power supply which is used is AC 220 V.

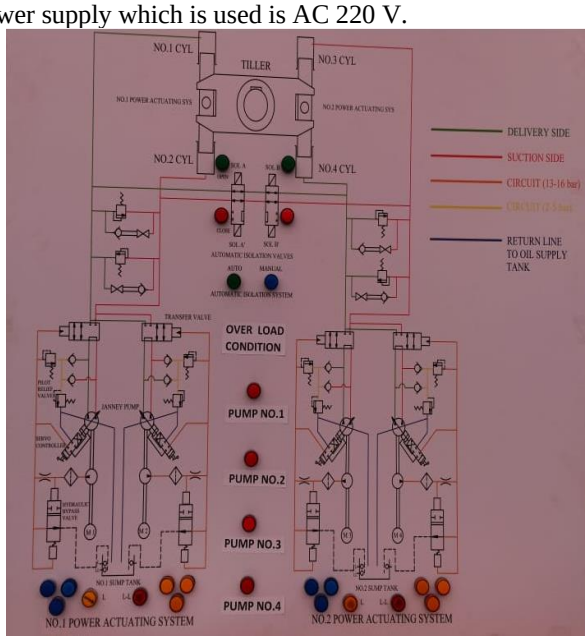


Figure 4. Developed LED Display Board

III. EXPERIMENTAL SET-UP, CIRCUIT DESIGN, TESTING AND OBSERVATION, COMPARISON AND RESULT

The display board indicates the entire operation of the isolation. It is connected with the other boards using electrical wires. In the event of any failure in the hydraulic oil piping, upon receiving an input from the toggle switches (used in place of float sensors), the relay logic control performs the operation according to its wiring logic and gives commands to the starter panel as well as the solenoid valves to perform the isolation, thereby saving the system from total failure due to loss of hydraulic oil.

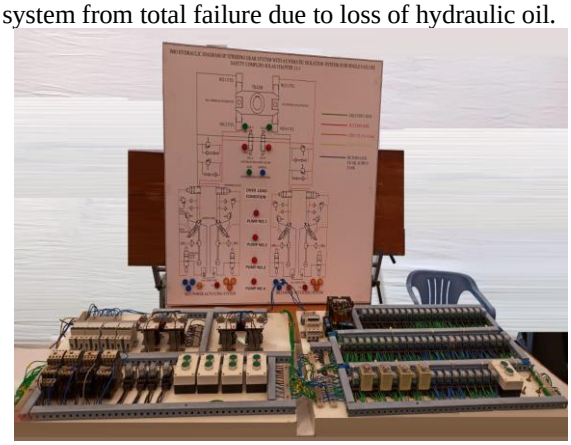
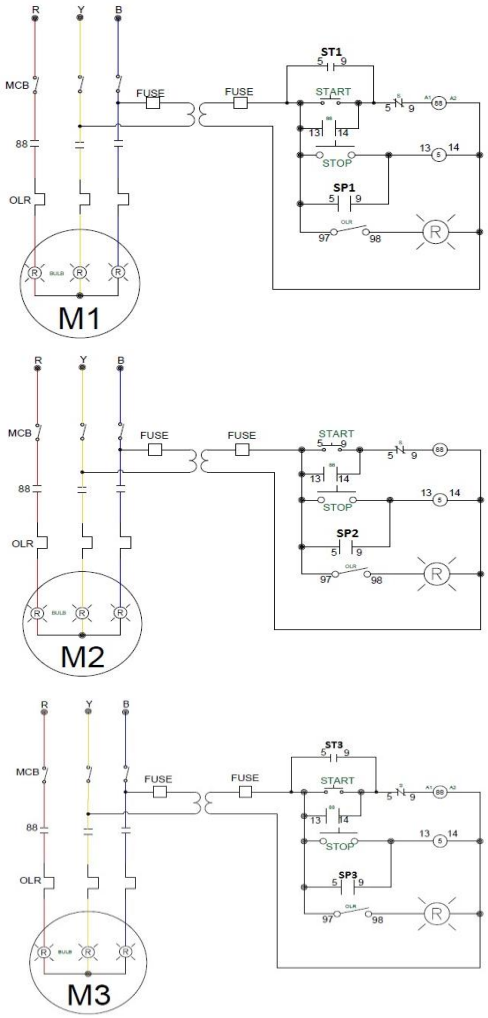
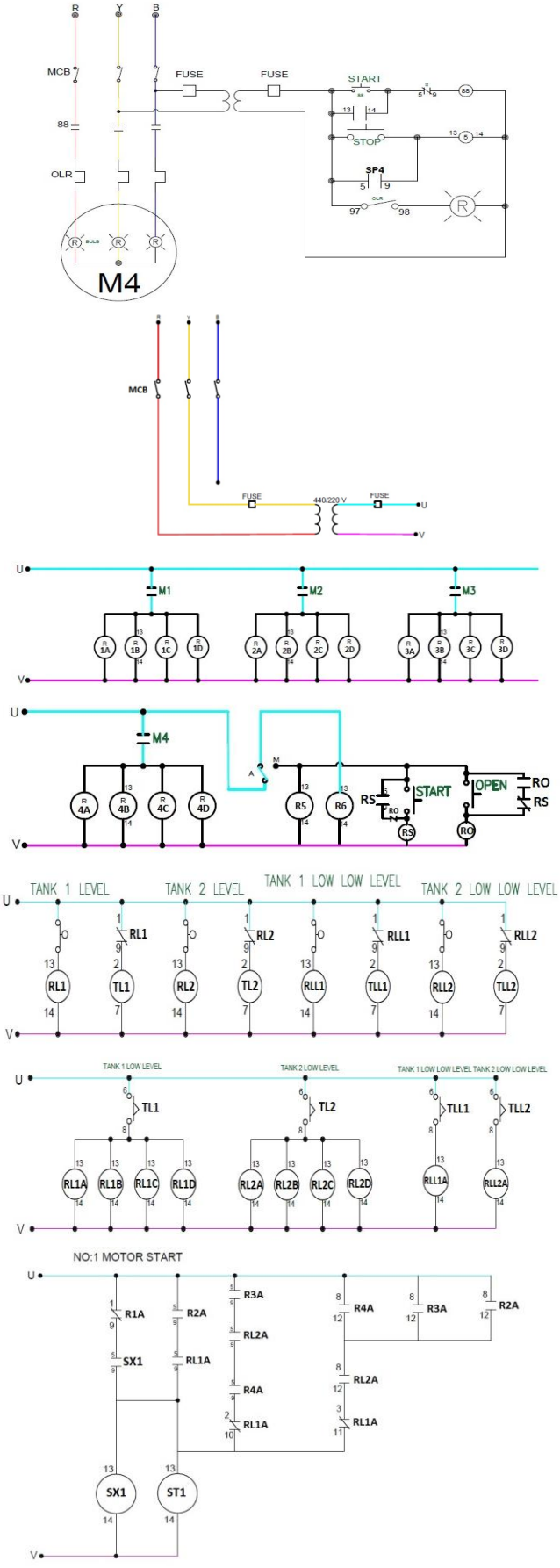


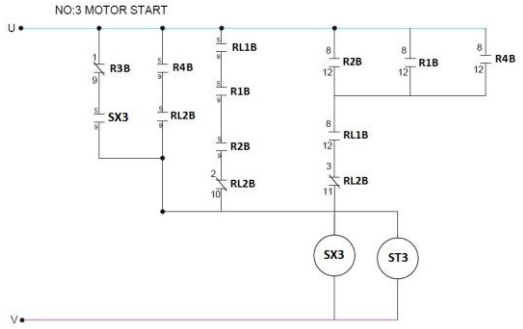
Fig 5. Experimental set up

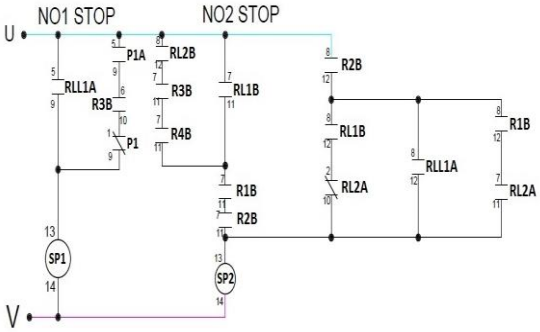
A. Electrical Circuit design [8]

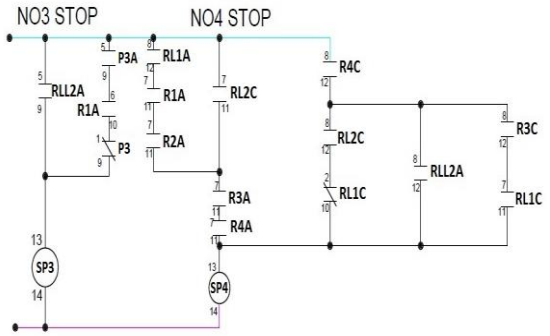
The schematic diagrams of the relay logic of the isolation system are given below which were developed using the AUTOCAD software. Except the starter panel with 440 VAC power supply, all the other boards have a power supply of 220 VAC.

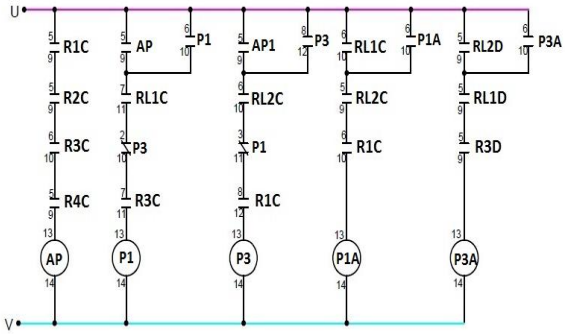


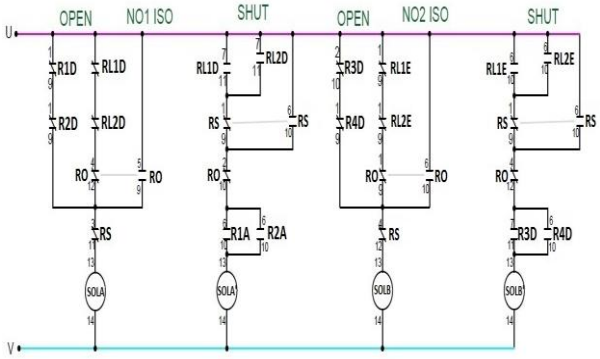

R
Y
B
MCB
FUSE
FUSE
START
88
OLR
STOP
SP4
M4
MCB
FUSE
440/220 V
FUSE
U
V
M1
M2
M3
M4
START
OPEN
RO
RS
TANK 1 LEVEL
TANK 2 LEVEL
TANK 1 LOW LOW LEVEL
TANK 2 LOW LOW LEVEL
RL1
RL2
RLL1
RLL2
TL1
TL2
TLL1
TLL2
TANK 1 LOW LEVEL
TANK 2 LOW LEVEL
TANK 1 LOW LOW LEVEL TANK 2 LOW LOW LEVEL
NO:1 MOTOR START
R1A
R2A
R3A
R4A
RL1A
RL2A
SX1
ST1



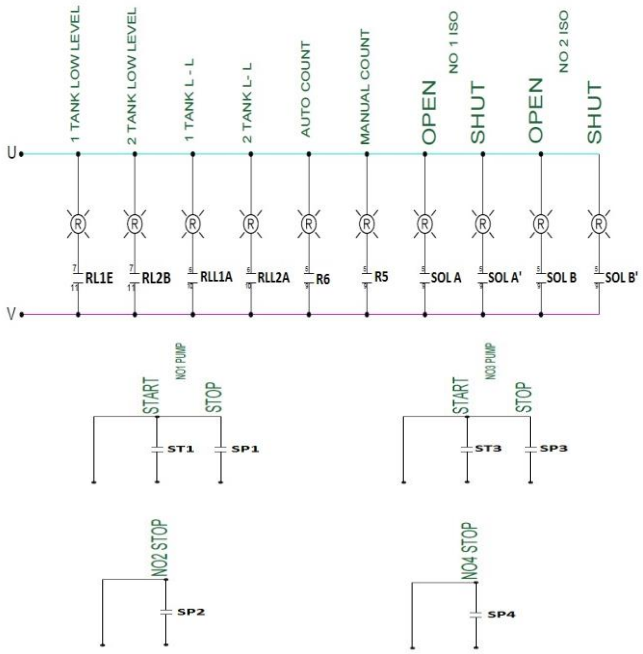








0	1	**2**	3	4	5	6	7	8	9		10	
									a	b	a	b
A	1	0	1	0	1	0	0	0	0	1	0	1
A’	0	0	1	0	1	1	0	0	1	0	0	1
B	1	0	1	0	0	0	1	0	0	1	0	1
B’	1	0	0	0	0	0	1	1	0	1	1	0
C	1	0	1	0	1	0	0	0	0	1	0	1
C’	0	0	1	0	1	1	0	0	1	0	0	1
D	1	0	1	0	1	0	0	0	0	1	0	1
D’	1	0	0	0	1	0	1	0	0	1	1	0
E	1	0	1	0	0	0	1	0	0	1	0	1
E’	0	0	1	0	1	0	1	0	1	0	0	1
F	1	0	1	0	0	0	1	0	0	1	0	1
F’	1	0	0	0	0	0	1	1	0	1	1	0



B. Testing and Observation Table

Table 1. Testing and Observation

Columns

- 0-Condition
- 1-Motor 1 (ON/OFF) Blue lights
- 2-Motor 2 (ON/OFF) Orange lights
- 3-Motor 3 (ON/OFF) Blue lights
- 4-Motor 4 (ON/OFF) Orange lights
- 5-Tank 1 low level Orange light
- 6-Tank 1 low-low level Red light
- 7-Tank 2 low level Orange light
- 8-Tank 2 low-low level Red light
- 9a-Isolating Valve NO.1 (Open) Green light
- 9b-Isolating Valve NO.1 (Shut) Red light
- 10a-Isolating Valve NO.2 (Open) Green light
- 10b-Isolating Valve NO.2 (Shut) Red light

Rows

- A-All pumps are running and tank 1 low level signal appeared
- A'-(In continuation with condition A) Tank 1 low- low signal appeared
- B-All pumps are running and tank 2 low level signal appeared
- B'-(In continuation with condition B) Tank 2 low- low signal appeared
- C-Pump NO.1 was running and tank 1 low level signal appeared
- C'-(In continuation with condition C) Tank 1 low- low signal appeared
- D-Pump NO.1 was running and tank 1 low level signal appeared
- D'-(In continuation with condition D) Tank 2 low signal appeared
- E-Pump NO.3 was running and tank 2 low level signal appeared
- E'-(In continuation with condition E) Tank 1 low signal appeared
- F-Pump NO.4 was running and tank 2 low level signal appeared
- F'-(In continuation with condition F) Tank 2 low –low signal appeared

C. Comparison Table

Table 2. Comparison

S. no	Manual Isolation System	Automatic Isolation System
1	System fault isolation time is more	Fault isolation time is less
2	System wholly depends on the competency of the operator	System can work independently without human interaction
3	If not operated properly and quickly, it may result in total failure of the steering gear system	Steering is possible even in the worst case
4	System depends on other equipment like sensors, alarm monitoring system	It works independently
5	Wrong operation of the valves can result in a devastating damage of the entire steering gear system.	There is no possibility of wrong operation

D. Results

Sensor Input	Set Delay	Operating time for Isolation
Toggle switch low level	10 Second	<1 Second
Toggle switch too-low level	5 Second	<1 Second

Table 3. Result

Upon activation of the toggle switch for low level (fitted in place of the float sensor), the automatic isolating system waits for the set time delay, after that it shuts the isolating valves in less than 1 second and stops the Pumps No 2 and No 4.

Upon activation of the toggle switch for too-low level, after the set delay, the steering gear motor (No 1 or No 3) in the defective side is stopped in less than 1 second and the isolating valve of the defective side is opened so that the steering gear system can still remain operational with the pumps on the healthy side system and defective side cylinders are by-passed.

E. Conclusion

In this paper, a robotic relay based isolating system has been designed and developed successfully for steering gear control of a ship. Its performance analysis has been carried out with a manual isolating system. Upon receiving input from the first level sensor of any tank, the robotic isolating system will isolate the steering gear system into two independent systems and upon receiving the input from the second level sensor, the defective steering gear system will be stopped and isolated. Whereas a manual isolating system is fully dependent on the competency of the engineer, and the time taken to isolate the defective system is more, which can result in serious problems. Hence the developed robotic control system is advantageous for the steering gear control and isolation in case of fault in a ship.

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