Indigenously Designed and Developed Control System for Sri Lankan Naval Vessels "Naval Propulsion and Steering Control" System

K Bombugalage and AB Arachchi#

Sri Lanka Navy

#akilalawan@gmail.com

Abstract— Obsolescence of spares for Leader In Propulsion System (LIPS), Netherlands engine/steering control system Fast Attack Craft (FACs) of Sri Lanka Navy (SLN), will be non-operational in the near future, and the manufacturer has provided a proposal for upgrading these at a cost of approximately Rs 93,9 Mn per craft in year 2017. Hence, this effort has been made by studying the existing system with the automation knowledge accessible. This study presents aspects of the engine and steering controls onboard P47 series FACs, by analysing the existing systems based on automation and the use of modern propulsion based on Programmable Logic Controllers)PLC .(Human Machine Interfaces)HMI (have been integrated for advanced monitoring and calibrating purposes which comprised a PLC based control system integrating sensors and actuators with commands given at the engine room, wheelhouse, and open bridge command panels .Processed command data are fed to actuators and the feedback have been obtained, thus forming a closed loop control system. These commands, feedback, and sensor readings are fed to PLCs and interfaced with the HMIs which indicate parameters in real time .Alarms and shutdowns have been set at the specific reference values and indicated on the monitoring displays. Controls are available at the engine room, wheel house, and open bridge for easy manoeuvrability as per operational requirement. The study covers the designing process, implementation process and PLC programming, HMI programming, simulation process, commissioning process, and testing process. Used PID controls in the feedback mechanism to optimize the control process variables are the most accurate and stable controller .The designed system was installed onboard P471 and tested several times under close supervision by experienced Senior Electrical Engineers as well as Senior Marine Engineers of SLN, prior to placing the craft as operational on 03rd January 2019. The cost for the project was only approximately a total of Rs. 3.6 Million which will save approximately Rs. 91.4 Million per craft.

Keywords: ***MMM (Mini Micro Module) and LMP (Lips Micro Processor), Machine Interface (HMI)***

I. INTRODUCTION

Designing and developing engine or steering control systems in the marine field is to be undertaken at a high standard where it needs to have proper insulations and a higher level of vibration resistance value. SLN Fast Attack Crafts are specially armed and they are equipped with highly standardized control systems and possess with above said qualities and from highly developed European countries. Carrying out deep studies about these systems and the gained experience during the past decade with marine control systems, made our way so clear about understanding the basics of control systems practically.

Omron CP1H high end type PLC which is an IP 65 rated and certified for the marine environment. Analog/digital external modules, relays, relay bases and RTC 100 (04 mA to 20 mA converting) modules were chosen for meeting the above requirement. The designed system was installed onboard P470 in the initial stage for more than 02 years and no major failures or defects occurred due to simplicity and also a depth of study about securing and proper mounting of the system make easy for background works.

Control signals from existed LIPS controls were bleached to the PLC based new control system. Interlocks and safeties were interfaced using the Ladder diagrams as appropriate. Important functions for armed craft such as **Battle override**, **Emergency Start/Stop**, **Backflush**, etc. were also given practically introduced and given major apprehension on them.

In addition to the existed LIPS features, newly introduced numbers of features such as Engine Alarms Log which can store the last 4000 alarms from each engine, Standby mode for the control system which saves power and lifetime of the essential components, home screen facilitated with steering and both engine critical parameters, etc. (Beckert, 2015).

Maintain the operational state of the LIPS control system is very difficult due to the obsolete of main PCBs such as MMM (Mini Micro Module) and LMP (Lips Micro Processor), also the Original Equipment Manufacturer (OEM) – Wartsila Netherlands Propulsion Services Pte, indicated that the production of above PCBs is no longer available. Hence, they forwarded a quotation for upgrading of 02 craft cost Rs. 178,977,684.43 in the year 2017.

II. APPLICATIONS

The Indigenously designed system is consisting with Engine controls as well as Steering controls. The marine engine is available with various types of pressure sensors (4mA to 20mA), temperature sensors (PT100/1000), limit switches, tachos, solenoids, etc. which are providing indications, alarms and shutdowns for the safety of the engine. This engine control system can be introduced for various types of marine engines of SLN such as,

1) 12V 604 Deutz
2) 12V 620 Deutz
3) 08V MTU TE 93
4) 12V MTU TB 94, etc.
5) Onan-Cummins Generator engine
6) Nothern-lights Generator engine

The designed steering control system also facilitates the smooth operation of solenoids for hydraulic cylinder operations and feedback from marine type potentiometers. Further, the system can install on a somewhat type of hydraulic driven steering system onboard identified types of Fast Attack Craft available in the Sri Lanka Navy. (marineinsight, 2017)

1) Marine Jet Power– Water jet propulsion- Sweden
2) Kamewa Water Jet – Rolls-Royce, German
3) LIPS – Watsila Netherlands
4) Pneumatic systems – Chinese

III. LITERATURE REVIEW

As per the internet surveys, PLC development began in 1968 in response to a request from a US car manufacturer (GE). The first PLCs were installed in the industry in 1969 and communications abilities began to appear in approximately 1973. The latest standard "IEC 1131-3" has tried to merge PLC programming languages under one international standard. We now have PLCs that are programmable in function block diagrams, instruction lists, C and structured text all at the same time.

The functionality of the PLC has evolved to include sequential relay control, motion control, process control, distributed control systems, and networking. The data handling, storage, processing power, and communication capabilities of some modern PLCs are approximately equivalent to desktop computers. PLC programming combined with remote I/O hardware, allows a general-purpose desktop computer to overlap some PLCs in certain applications.

The main difference from most other computing devices is that PLCs are intended for the tolerance of more severe conditions (such as dust, moisture, heat, cold) while offering extensive Input/output to connect the PLC to sensors and actuators. PLC input can include simple digital elements such as limit switches, analog variables from process sensors (such as temperature and pressure), and more complex data such as that from positioning or machine vision systems. PLC output can include elements such as indicator lamps, sirens, electric motors, pneumatic or hydraulic cylinders, magnetic relays, solenoids, or analog outputs. The input/output arrangements can be built into a simple PLC, or the PLC may have external I/O modules attached to a computer network that plugs into the PLC.

IV. CERTIFICATE OF COMPATIBILITY

1) PLC

PLC Brand	: Omron
PLC model number	: CP1H
Country of Origin	: Japan
Shock resistance	:30 g, 3 pulse each axis
IP rating	:IP54
Max. working temp.	:-20C to + 60C
Vibration withstand max peak-peak	:10-500Hz, 3 g, 0.015"

2) Touch Panel – HMI

HMI Brand	: Samkoon
HMI model number	: Samkoon AK& SK

Country of Origin	: China
Shock resistance	:20g, 3 each axis
IP rating	: Front IP65, Back IP54
Max. working temp.	: -10C to + 70C
Vibration withstand	:10-500Hz, 3g

3) Control Relays

Brand	: Schindler Electric
model number	: Zelio series
Country of Origin	: China
Mechanical durability	: 30,000,000 cycles
Electrical Durability	: > 100,000 cycles for resistive loads at 12A, 250V
Max. working temp.	:-10C to + 70C
Vibration withstand	:10-500Hz, 3g

Device certificates:UL 508, CSA C22-2, EN/IEC 61810-1

V. DESIGN SPECIFICATIONS

The large engine control cabinet of LIPS, located in the engine room which faced high temperatures, moisture, smoke, etc. Hence the manufacturer; LIPS had many difficulties rectifying any defect on this while sailing.

Designed system wire connections were taken distinctly and decided to locate inside an Air Conditioning compartment next to the engine room (OIC/2IC Cabin) which facilitates and provides a longer lifetime as well as increased working efficiency to the system. Further, a designed Engine room control panel was introduced with a touch screen display (HMI) for monitoring all the parameters of the engines.

Figure 1. Designed Control Box for Engine Room

The designed control panel was including all the critical functions such as Engine Start/Stop, RPM increase/decrease, etc. with the Jog switches, selector switches. For the steering system, introduce 12.1 inches common HMI for Closed Bridge to monitor both the engine and steering parameters in one screen and 7 inches common display for Open Bridge for easy operation which simplifies the control panel and can identify the details/data at the real time.

Figure 2. New Control and Monitoring Panel

The control system architecture consists of 02 No's of PLCs with required sensor inputs at Engine Room panel and 04 No's of PLCs at Wheel House (Closed Bridge) to work as engine data transmitting to HMIs and for the steering system. All the Analog/Digital inputs from Engine Room and Wheel House/Open Bridge throttles were sent to the Engine Room through intermediate PLCs and processed within the Engine Room PLCs.

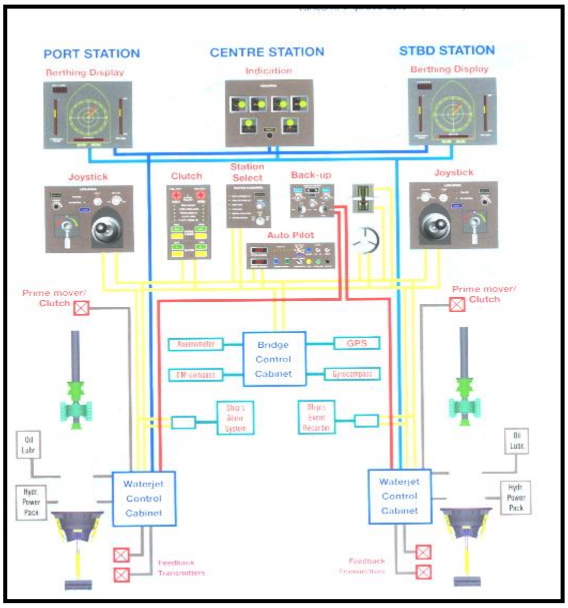

Figure 3. Existing LIPS Block Diagram

Other Inputs/Outputs of Wheel House and Open Bridge will be controlled via the Wheel House PLC and connected to the Engine Room PLC using serial communication interfaces. PLC to PLC communication made using RS 485 protocol.

A. Designing of Engine Control System

Used sophisticated panel boxes at Engine Room for mounting of designed engine controls to avoid vibration and mounting losses and laid wiring connections from engine sensors to engine room control panel and numbered as our NPSC diagrams.

Figure 4. Introduced Engine Control Panel

B. Designing of Steering Control System

LIPS consists of analog indication gauges in Open Bridge and Wheel House compartment for steering, bucket and RPM. It required calibration one by one when replacing of PCB or module when occurred any defect on it. Hence, the designed system introduced a touch screen display for indications such as steering, bucket and RPM also for the calibration. However, remain separate analog gauge for RPM at both locations.

Figure 5. Designed HMI for Closed Bridge

The introduced HMI at Closed Bridge is also designed to give Steering as well as both engine data on its home page. When it touches an upper potion, shall shift to a separate Steering data page and when it touches the lower left and lower right, shall shift to Port engine data and Stbd engine data respectively. Furthermore, introduced 7 inches HMI for Open Bridge to give clear steering indications and only critical engine data.

Separate 02 PLCs were used for the Steering Control system (Port & Stbd) where it connected to all sensors of the water jet system from one end and Steering Wheel & Throttles from the other end. (Arneson, 2020). The PLCs are mounted on the top of the previous LIPS mounted plate where the Air Conditioning environment is located to the system.

VI. PERFORMANCE

Carried out considerable sea trials successfully at the inner harbor as well as the outer harbor at Trincomalee since 02nd December 2017. Engine parameters are monitored separately by mechanical gauges, non-contact IR tacho-meters and observed same values are displaying on the monitoring display (HMI). Also steering parameters were monitored such as hydraulic oil working pressure, temperature by mechanical gauges and all were under the permissible level.

Turning circles and maneuvering of the craft is very much easy and smooth compared to existed system LIPS. Performance has been monitored from Open Bridge visually and the speed of the craft compared to other craft when operating a single engine, it is very much efficient and the speed of the craft also higher than the LIPS.

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Turning circles and maneuvering of the craft is very much easy and smooth compared to existed system LIPS. (Anon., 2020). Performance has been monitored from the Radar onboard and the speed of the craft compared to other craft of the same series is higher than the LIPS.

Table 1. Engine Parameters recoded during Sea Trials

Location	**Engine RPM (in load condition)**	**Speed by GPS**
Trincomalee harbor	700	8.5 Knots
	800	9.2 Knots
	900	10.3 Knots
	1000	11.5 Knots
	1100	12.3 Knots
	1200	13.2 Knots
	1300	15.8 Knots
	1400	17.1 Knots
	1500	22.0 Knots
	1600	27.9 Knots
	1700	30.8 Knots

VII. REDUNDANCY IMPLEMENTATION

There is a backup control panel board at Engine Room, Wheel House and Open Bridge. All the inputs and output of the designed engine control panel (either PORT or STBD) can be switched to the backup controller to completely isolate the normal PORT or STBD controller. This enables the boat to operate in case of a failure in any of the systems within the engine controller and enables the components to be replaced at the operational stage. (www.crossco.com, 2020).

The same works for the Wheel House and Open Bridge. The redundancy PLC unit takes all the I/O from the general PLC unit and operates the same way as the general PLC. The HMI panels and indicator panels are not redundant. But a failure of one of these components will not affect the running operation of the engine as the engines can operate without indicators or touch panels.

The key operations (Start PB, Stop PB, Emergency PB,etc) are supplied at the redundancy controller interface so that separate Start, Stop, Emergency PBs will be installed at the HMI panels to be used at redundancy operation.

VIII. CONCLUSIONS AND FUTURE WORK

An indigenously designed Engine/Steering control system is a cost saving of 1/8 compared to an existed system made obsolete by the manufacturer. Also, this designed system can be separated into two independent systems like Steering Control System and Engine Control System with some modifications both the systems can installed many types of existing control systems use in SLN.

1) SLNS Sayura D86 System Engine/Alternator/Axially Equipment, etc.
2) SLNS Shakthi Engine Control System
3) SLNS Udara/Prathapa Engine Control System
4) P47 Series Fast Attack Craft Engine/Steering Control System
5) P46 Series Steering Control System
6) Various Generators/Alternators

Programmable Logic Controllers developing day by day. (www.crossco.com, 2020). Hence the designed system also has to be modified and standardized day by day. Knowledge about programming and designing has to improve with technology and it will help to make standardized and higher quality systems for Sri Lanka Navy.

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AUTHOR BIOGRAPHY

Akila Bamunusinghe Arachchi was born in Balangoda, Sri Lanka in 1988. He received his BTech degree in Electrical and Electronics Engineering from Jawaharlal Nehru University, New Delhi, India. From 2014, he has engaged in many research and development (R&D) activities in electrical and electronic field. He has served in Sri Lanka Navy as an Electrical and Electronic Engineer in R&D and fleet units. He is presently serving as a senior Electrical and Electronic Engineer of Electrical New Design Center (E) of Sri Lanka Navy.