Developing of Emergency Safety Device Module Under Vessel Integrated Automation System for Dual Fuel Diesel Engine

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Abstract. Using gas as a fuel of the ship’s main engines give challenges in term of efficiency, fuel prices, low emission, and safety behavior. Gas characteristics need particular attention due to higher flammable, explosive, and hazard gas leakages. Adopting gas as fuel onboard a ship insists on a higher level of safety as guided by the IGF Code. Conventional safety devices installed in the conventional diesel engines only aware of its combustion sensors. This study intended to develop a new PLC module that is capable of an automatic stop of the dual fuel diesel engine under any programmable emergencies. The developed module is integrated under the Vessel Integrated Automation System. The logical program manages the system to assure the continuous fuel service and stop the system when pre-defined hazards happened. Hazards are predicted from excessive pressure and temperature, flow rate, and gas leakages. The module in a form of software and hardware will be built using industrial tools.

Keywords: Emergency Safety Device, PLC Module, Control System, Integrated Automation, VIAS, Dual Fuel Diesel Engine

1. Introduction
Working with natural gas as fuel is a specific task for a marine diesel engine. The most important issue is safety [1]. In term of safety, there are some requirements that must be fulfilled by ship designer and ship operators when they work in the gas medium. The ship’s designer should be capable of arranging both mechanical and electrical systems that warranty all systems that can work perfectly and sustain along ship lifetime.

Today’s technology especially in the shipping industry is dominated by electronic systems. Modern vessels are mostly provided by certain control and automation systems that navigate the voyage and all of the internal components and systems. There are several levels in the automation system as shown in Figure 1 below [2]. The growing of the population makes the prices of the automation system lower and lower. The sophisticated technology becomes today’s standard. Furthermore, the automation system is a straightforward way to perform autonomous ship technology or also called as a sea-drone [3].

Automation offers many benefits in the operation of any type of ship. The most important is the safety and security aspects that always place in the paramount position [1]. The integrated automation system contributes better performance to optimize the works of ship equipment [4]. This study set up one of the new implementations of the Vessel Integrated Automation System (VIAS) by built a sub-program called an Emergency Safety Device (ESD) to support the research in the modification of a single-cylinder diesel engine using CNG as fuel beside of HSD [5]. Working with gas as fuel produces several risks related to the safety of the engines and its surrounding area, including operator or researcher. In the normal situation with engine standard parts there is some note burning gas is risky to engine damages. Modify with the target to conduct a bigger power could bring more hazards in this research work [6]. It is a good idea to anticipate the possible danger may be caused by engine explosion or fire. A device such as an ESD can detect any sign of danger earlier and it can react automatically to
shut down the engine. On the same side, refer to the main objectives of this research [5] to investigate the maximum capability of the material piston to resist incoming combustion power and heat, then optimize the control accuracy of the EDS could become a challenge in this study.

Figure 1. Hierarchy in the Automation Technology

The existence of ESD is in urgent in this research that it should come together with any controller and monitoring system to record engine performances during experimental works, then an integrated one is a better choice. The works of the engine running, monitoring, and finally, data collecting must be run under a safe environment especially when the gas is used as a fuel.

2. Literature Review
TIER III of MARPOL Regulation 13 has been on the way to come into forces globally [7]. The delay doesn’t mean cancel and many countries no obvious about that. One of the methods to deal with TIER III is using gas as the engine fuel. Due to the redundancy with the availability of diesel fuel onboard a ship as required by IGF Regulation than the dual-fuel technology has become the best choice [8].

There are many research activities to do convert the original diesel engines to be dual-fuel [6]. A gas such as LNG or CNG cannot be burned directly inside the diesel engine combustion chamber [5]. At least two main techniques can be chosen for dual fuel processes; put the compressed natural gas (CNG) together with air intake flow then common diesel fuel at the compression stroke injected to perform burn fuel, then in the second cycle (Fig. 2 left) and respectively the flowing of air intake and CNG will follow the continuous combustion [9]. The second technique is called the direct injection gas burning (Fig. 2 right), pilot diesel fuel injected to perform initial firing then subsequently gas injected and regularly the engine running by dominated gas fuel [8].
Figure 2. Diesel Ignited Dual Fuel System (left) and Direct Injection Gas Burning System (right)

Due to the possibility in terms of transport phenomenon or chemical knowledge that the energy content of gas by HHV is lower than diesel fuel than to achieve similar power output, then the previous researcher wants to further investigate by improving gas quantity with doing increase the area of the combustion chamber. A new piston of a single-cylinder experimental engine [5] is created with a bigger volume of the bowl to represent the higher volume. The effort in terms of mechanic knowledge may cause damage in the combustion area due to higher power [9] caused by combustion energy. Even many information already state that the existing gas engine face some potential damage problems in a certain component [10]. It is the basic idea why the ESD is in high demand for the research work. ESD will keep all safe settings to prevent any potential problems such as a higher increase of temperature, pressure drop, overpressure, gas leakages, in-normal vibration, noise, over-speed, overload, knocking, etc. ESD will shut down the diesel engine [3] for any potential fails. The researcher can evaluate the data output and examine the engine for any curious problems.

The common controller diagram for the dual fuel diesel engine system can be shown in Figure 3 below.

Figure 3. Schematic controller system for Dual Fuel Diesel Engine
3. System Setup

Understanding automation is not complicated as a decade before. Graphical User Interface (GUI) based and latest tools make everything easy and fast [2]. Amazing fibre-optic technology brings flash-internet that gives the user good optional online as well as offline. Working by cloud could cope with the difficulty of heavy type computer rendering such CFD, 3D solution, and others.

ESD is developed based on the VIAS (property of Praxis Automation) that is already established and proven installed inside more than 4500 ships around the world. This system was fully available in Indonesian Navy vessel PKR-105 and the predecessor SIGMA Class. Praxis Automation is one of the automation company [4] which has developed a special feature called as Internet Ship View (ISV) that it makes possible any shipping head-quarter in the land to monitor all VIAS operation, recording, and even acting several classified duties such as start/stop the engine for any high-level security in the crucial event as mention before [3]. ESD module will be developed under the VIAS platform.

3.1. Basic Arrangement of ESD

Safety device unit mostly available built-in at a diesel engine. But this engine test bench is structured by using a modified engine from single-cylinder diesel engine brand Yanmar TF85MH [11]. The engine planned to control an electrical generator to maintain load during experimental works. Three units of the proposed modified pistons will be tested under certain gas to diesel oil portion that possibly causes higher combustion power and it can be pushed the engine construction and its components into its safest limit. ESD functioned as the main device or as a complementary device that automatically capable off stop gas supply and then the diesel oil supply to prevent any accidents. ESD arranged to built-in into an existing standard VIAS system that capable of retrieving any data from ECU to perform EMS (Engine Management System).

3.2. System Setup

Based on the diesel engine experimental setup as shown in Figure 4, then the ESD is installed in an integrated module with PLC which is can be used to control the operation and data acquisition of the test bench [5]. The capability of ESD and VIAS module in handling multi-input and output make it possible to monitor and control up to 396 hardware points.

Figure 4. Position and function of the Emergency Safety Device (ESD)
Distributing processor unit will connect to the alarm panel system and all data visualized on a TFT monitor with built-in marine PC that operation by touchscreen is also available. The idea will propose to the system developer in a certain scale depend on the research budget. Detail of the PLC schematic diagram can be shown in Figure 5.

![Figure 5. Example of Schematic diagram in ESD system Control Engine](image)

4. Data and System Analysis

Safety will be placed in the highest priority in this research works. Any possibility of an accident already predicted in any circumstances [1]. Using non-original components may be coming with hidden risks even contingency plans applied by choosing certified and experienced components. The experimental works must conduct safety precautions as perfectly as possible. ESD must be capable of controlling the hazard situation without obstructing the objectives of the research goals. It would be a big challenge to setup an emergency limit in any parameters. The accuracy of ESD highly influences the demand to investigate the maximum strength of new piston arrangement. It requires step by step adjustment to capture the safest results of the experiment. It may be time and cost consuming but safety first.

In this scope of preliminary research, it will not use a proper ESD system such as industrial grade VIAS from Praxis yet. The common brand such as Arduino PLC is already used in the laboratory to control gas portion and gas injection timing during the experimental works. The PLC module will be modified to integrate with the proposed ESD system. The basic idea of this research work to prevent any potential accidents then can be improved in a larger scheme such as the application of VIAS-ESD onboard a ship for real projects.
5. Conclusion
The virtual panel of VIAS displayed in monitor screen offers many advantages technically and economically. A cheaper system can easily accommodate a much more virtual system and its equipment without any constraint to the bridge console space. Progressive alarms and signals come from any emergencies situation that can display override on the screen wherever the sources come. ESD with the optimized backup systems becomes an eye on the control system that possible to prevent any late acts due to the initial causes of potential accidents. Especially when it applied to the higher risk system such as main diesel engines that burn natural gas such as CNG as fuel.

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