Application of Microcontroller (MCU) on Marine Close Loop Exhaust Gas Scrubber Circulation Pump Control

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ABSTRACT
Exhaust emission is becoming global issue in maritime industries. Since the implementation of the regulation, various method was introduced maritime industry with aim of reducing the pollutant releases into atmosphere including exhaust gas scrubber system. Exhaust gases produced during combustion is directed to pass through scrubber system where the exhaust gas is cleaned before release to atmosphere. This journal will explain the control system developed by using the microcontroller to control the circulation of water in the system.

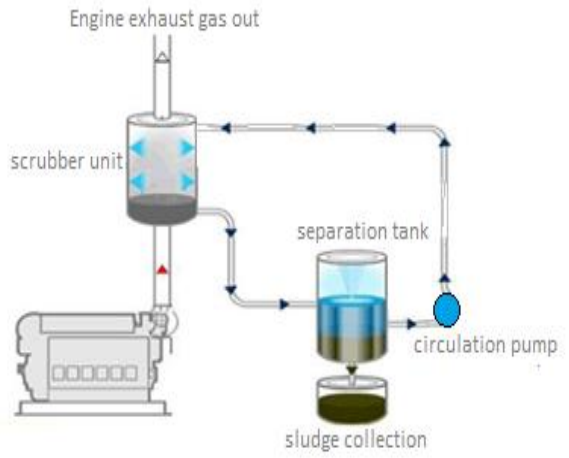

Figure 1: Basic system of exhaust gas scrubber [1]

KEY WORDS: *PIC microcontroller, Tank Level Controls, MCU*

NOMENCLATURE

LH	*Level High*
LL	*Level Low*
LED	*Light Emitting Diode*
MCU	*Microcontrollers*
PDLP	*Plastic Dual in Line Package*
PIC	*Peripheral Interface Controller*
LCD	*Liquid Crystal Display*

1.0 INTRODUCTION
Maintaining water level in separation tank of closed loop exhaust gas scrubber system is most important factor to ensure the optimum efficiency of the system. This journal will explain how the water level control system for exhaust gas scrubber is being developed by using a 16F84A microcontroller. This microcontroller will act as central processing unit which to control the circulating pump, trigger an alarm and also by providing input and output signal used to project the display on LCD screen.

1.1 Similar System
System had been developed are designed to work with closed loop exhaust gas scrubber system which is critical to maintaining water level inside the separation tank to ensure the efficiency of the system [2]. Currently the system is using conventional electrical component to run the system. With regard to that idea this control system is designed with aims for a low-cost device, as well as the operation of a microcontroller unit (MCU)-based system

1.2 Current System
At present there are 3 main design in scrubber system in industry:
1) Open-loop scrubbers is a system where the sea water is pumped into scrubber unit to create water spray resulting exhaust passing through it being cleaned. The water then releases back to ocean [4].
2) Closed-loop systems can de define as circulating the fresh water

through scrubber unit and the drain water is then passing through separation tank to separate carbon and water treatment is carried out [4].
3) hybrid scrubbers can operate as either open or closed-loop systems and may be able to fluctuate between freshwater and seawater [4].

1.3 Proposed System

A reliable, inexpensive, configurable, easy to be operated electronic control system is proposed to deliver a beneficial effect for the ship operation and environment. Close loop system is having better advantages compare to open loop in term of effluent of carbon released to sea. Within this system, all by product are kept onboard and will disposed at approved reception facilities.

2.0 METHODOLOGY

Solution of fresh water and caustic is sprayed inside scrubber unit with aim to clean the exhaust gasses passed through scrubber Unit. Sprayed solution is then collected in separation tank. Collected water from scrubber unit will go for carbon separation inside the separation tank. As a continuous process, tank level and circulation pump pressure are constantly monitored when the system is running. The level is monitored by 2 unit of float switch designated as high-level sensor and low-level sensor installed on tank and the pump pressure is monitored via pressure switch installed on piping on pump discharge line. If the level switch or pressure switch is activated or any open circuit occur in alarm circuit, alarm will be triggered by the control circuit MCU and activate the visible and audible alarm and also activating output to display MCU then display the existing alarm status on LCD display unit. This warning is in combinations of LCD display, LEDs and buzzers. Incase alarm triggered; operator may refer to trouble shooting chart for fault finding. Table 1, Shows the trouble shooting possibilities.

Table 1: Trouble Shooting Chart

Trouble Shooting Chart	Leaking Piping /tank	Header Tank Low	Clogged Return Line	Clogged Pump Suction	Open Circuit in Sensors	Leaking Cooler	Over Collection of Soot In Separation Tank	Pump Accidentally Stopped	Pump Wear Over Limit	Sensor Fault	Power Failure	PIC Failure
Low Level Alarm	●	●	●		●	●				●	●	●
High Level Alarm				●	●		●	●	●	●	●	●
Low Pressure Alarm	●	●	●	●	●	●		●	●	●	●	●

2.1 Component

The components of the system consist of PIC16F84A, this Microcontroller designed with 18-pins. Sensor switches that are installed to the separation tank and pump discharge line. Motor for circulation pump is continuously run while system in operation except during high level alarm, Relay are use as switching method to operate higher power circuit which use for pump motor driving. Relays are also use to switching the power to buzzer circuit. Figure 1 shows the sensor arrangement and flow of control

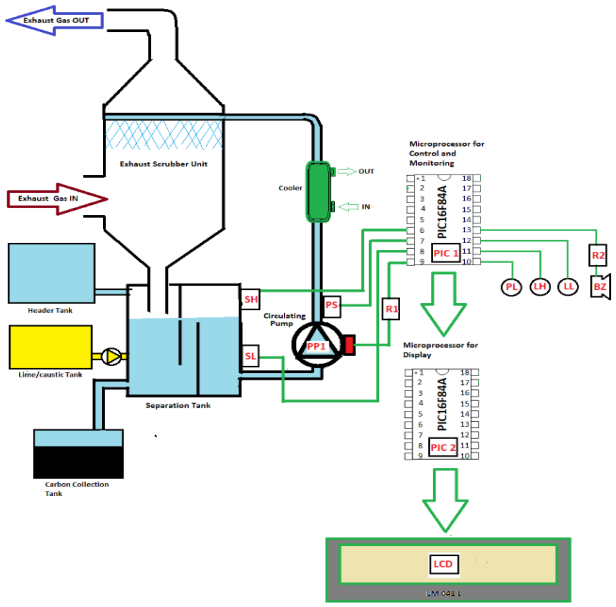

Figure 2: Sensors arrangement and signal flow diagram

2.2 Operations

The operation concept is described below:

- Initially fresh water is filled inside the separation tank until below high-level alarm point.
- When the circulation pump (PP1) is started, the control system will start to monitor the level and pressure.
- (PIC1) will monitor the circuit continuity of level switch (LL), (LH) and pressure switch (PS).
- In normal running condition, (PIC1) will sense all sensor circuit are in close condition.
- The (PIC1) will trigger the normal running output to (PIC2). The (PIC2) is then trigger the < SYSTEM NORMAL > output signal to be display on (LCD).
- In case of low-pressure switch (PS) is activated or any faulty occur on its circuit, the (PIC 1) will trigger the high output signal to LED (PL), Buzzer (BZ) and (PIC2). The (PIC2) is then will send High output signal to (LCD) and displaying <ALARM> <PUMP LOW PRESSURE>.
- In case of low-level switch (SL) is activated or any faulty occur on its circuit, the (PIC 1) will trigger the high output signal to LED (LL), Buzzer (BZ) and (PIC2). The (PIC2) is then will send high output signal to (LCD) and displaying <ALARM> <TANK LEVEL LOW>.
- If high level switch (SH) is activated or any faulty occur on its circuit, the (PIC 1) will trigger the high output signal to LED (LH), Buzzer (BZ) and (PIC2). (PIC 1) also trigger signal low to stop the pump via relay (R1). The (PIC2) is then will send High output signal to (LCD) and displaying <ALARM> <TANK HIGH LEVEL>.
- This operation can be simplified and shown in table 2, shows the logic of the operations

Table 2: Truth Table.

PIC 1													PIC2				LCD DISPLAY
INPUT				OUTPUT									INPUT				
Start Button	High Level Switch (SH) (Pin_RB0)	Low Level Switch (SL) (Pin_RB3)	Pressure Switch (PS) (Pin_RB2)	Output 1 Normal (Pin_RA0)	Output 2 High Level (Pin_RA1)	Output 3 Low Pressure (Pin_RA2)	Output 4 Low Level (Pin_RA3)	Circ. Pump (Pin_RB3)	LED for Low Press Alarm (PL) (Pin_RB4)	LED for High Level Alarm (LH) (Pin_RB5)	LED for Low Level Alarm (LL) (Pin_RB6)	Buzzer (BZ)	Input 1 Normal (Pin_RA0)	Input 2 High Level (Pin_RA1)	Input 3 Low Pressure (Pin_RA2)	Input 4 Low Level (Pin_RA3)	
0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	"SYSTEM READY > PRESS START TO RUN SYSTEM"
1	1	1	1	1	0	0	0	1	0	0	0	0	1	0	0	0	"SYSTEM NORMAL > PUMP RUNNING > PRESSURE NORMAL > TANK LEVEL NORMAL"
1	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	"ALARM > TANK LEVEL HIGH"
1	0	1	0	0	0	0	1	1	0	0	1	1	0	0	0	1	"ALARM > TANK LEVEL LOW"
1	0	0	1	0	0	1	0	1	1	0	0	1	0	0	1	0	"ALARM > PUMP LOW PRESS"

2.3 Microcontrollers

The closed loop exhaust gas scrubber water circulating system is governed by a microcontroller which is a small computer that is installed in a circuit and controls a single device operation. This is accomplished by using its central processor to interpret data received from its I/O peripherals. This system developed is using PIC16F84A (Figure 3), microcontroller. PIC16F84A is 8-bit Microcontroller that was introduced by Microchip Technology (formerly known as " Arizona Microchip") with the interest of making electronic tasks easy that require minimum skills to work with. The PIC16F84A has 64 bytes of EEPROM (which is mostly used for data storage), 1K programmed memory (which means the amount of code that can be burned within the controller), and 68 bytes of data memory (RAM), and it out performs its processor in terms of compatibility and programmed protection [3] [4].

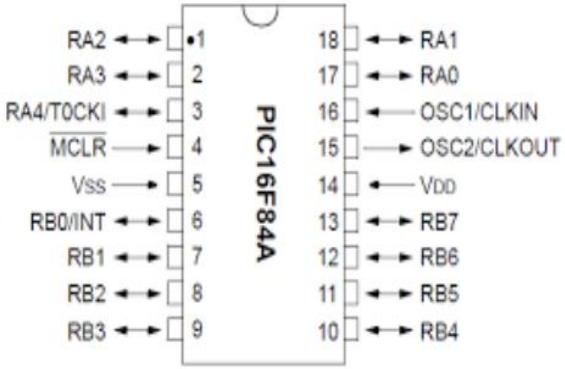

Figure 3: PIC16F84A Microcontroller Pin assignment (PDLP) [3]

2.4 Software

The microcontroller's codes are written, edited, compiled, and programmed using the "C compiler for the PIC MCU." This compiler, in conjunction with the PicKit2 programmer, allows the microcontroller to be customized in high-level programming languages. The algorithm of the codes will decide the state of the parts by actuating the microcontrollers input - output ports taking into account the particular tasks. The entire system's basic capability is to enable a timed interval of microseconds, acknowledge sensor inputs, and trigger the outputs by enacting the Alarm or the Motor.

2.5 Programming Description

There were 2 sets of instruction codes prepared for this system, codes for control and monitoring MCU and codes for LCD display MCU. The program is prepared in PIC C compiler program, compiled and then entire process is embedded in designated MCU of the process. This system is governed by PIC16F84A microcontroller.

2.6 System Flow

Once the system is started, the MCU will order the circulation pump to run. When the system is running normally, Control MCU will constantly monitoring the water level inside separation tank and pump pressure. The MCU then will intelligently decide on the next course of action as per prescribed code burn into it either activating the Motor automatically or triggering the alarm to allow the person in charge on the vessel to take further action.

The whole process can be described as in process flow chart as shown by figure 4.

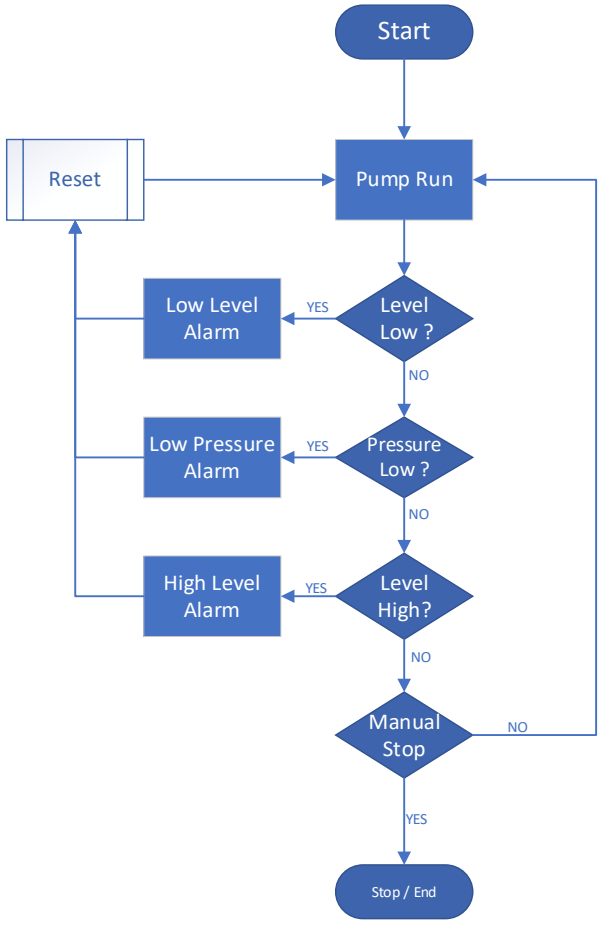

Figure 4: Flowchart of the system

2.7 Circuit

Two MCU are assigned, the MCU 1 is assigned for pump control and level monitoring while the MCU 2 serve as LCD display controller.

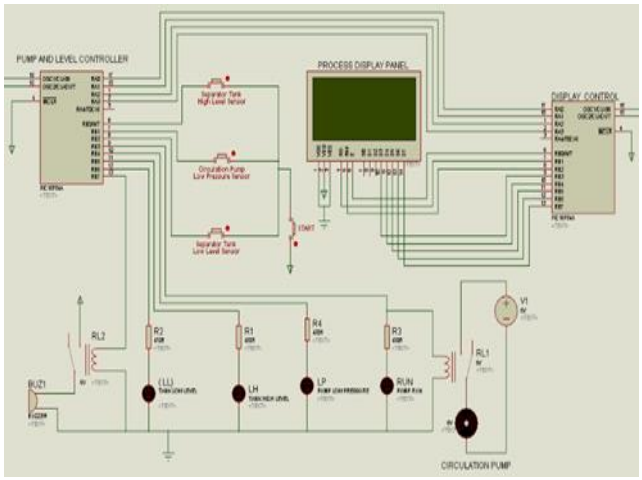

Figure 5: Designation of MCU

Both MCU are interconnected at port A. port B of Pump and Level Controller MCU are dedicated for sensors inputs, Output for alarm indications and controlling the pump relay input. On Display Control MCU, port A are assigned as input port from master MCU and port B are dedicated for output to process display panel.

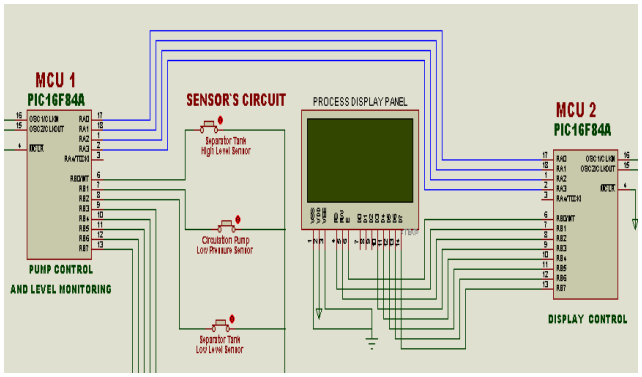

Figure 6: Interconnection between two MCUs

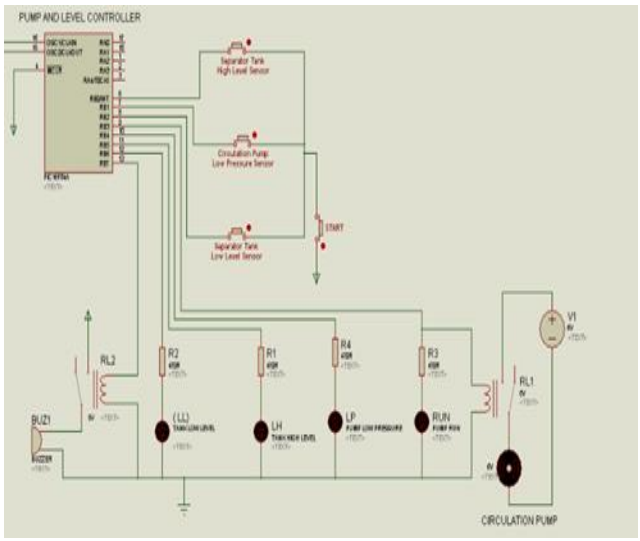

Figure 7: Input, Output and Alarm Circuit of MCU 1

Once the liquid in circulation tank reaches the high level or low level or low pressure, the alarm will automatically trigger by the MCU, to indicate an immediate attention is needed by the crew of the vessel. To be complied with marine standards, visual and audible alarm are incorporated in this system.

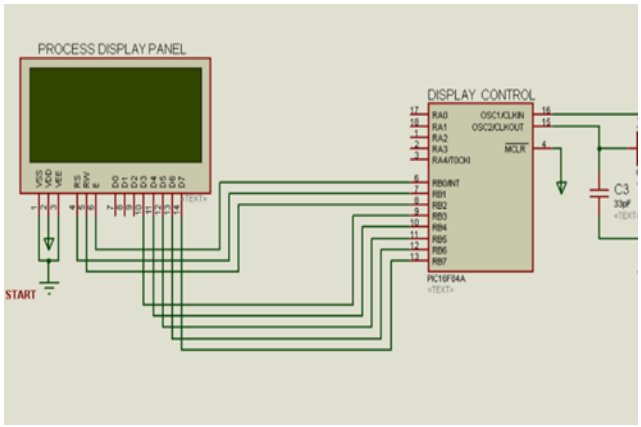

Figure 8: Display Control circuit

Operation of Display Control MCU is based on the input signal received by Pump and Level Controller MCU at port A. LCD display are depending by output signal of Display Control MCU assigned to Port B. Input and output configuration of Display Control MCU can be define as table 3.

Table3: Input signal and LCD display Configuration table.

PIC2 INPUT				LCD DISPLAY
Input 1 Normal (Pin_RA0)	Input 2 High Level (Pin_RA1)	Input 3 Low Pressure (Pin_RA2)	Input 4 Low Level (Pin_RA3)	
0	0	0	0	"SYSTEM READY > PRESS START TO RUN SYSTEM"
1	0	0	0	"SYSTEM NORMAL > PUMP RUNNING > PRESSURE NORMAL > TANK LEVEL NORMAL"
0	1	0	0	"ALARM > TANK LEVEL HIGH"
0	0	0	1	"ALARM > TANK LEVEL LOW"
0	0	1	0	"ALARM > PUMP LOW PRESS"

3.0 CIRCUIT DESIGN SIMULATION

By using software Proteus v7.6, the circuit was then replicated and tested. The crucial components for this circuit were chosen prudently through the software library and connection were done by lines. CCS C compiler were used for program compilation, while PicKit2 were used to load the output (hex file) of the program into PIC microcontroller. The circuit used for simulation is given in Figure 5. Mainly, this circuit consist of two controllers. MCU 1 for level and pressure monitoring inputs, pump control and MCU2 is designated for display control controller. Both interconnected at Port A of each MCU.

4.0 RECOMMENDATIONS

Controlling the liquid level are the main objective for this project, whereas to make sure the level for tank will not be too low, too high, or low pressure on the pump that will damage the equipment. As changes happen, programmable MCU can be utilized to control the components. More scenario can be explored, analyze, and studied using this program and controls

.

5.0 CONCLUSIONS

As the water level and pump pressure is critical in operation of Closed Loop Exhaust Gas Scrubber System, this proposed system will ensure the occupational safety on board by minimizing the needs for the crew to frequently moving to check the status of tanks and circulating pump by themselves and the protection of the equipment or machines as well. This system could further be improved by introducing new type of microcontroller in near future which can handle more input and output. By interfacing the system with sophisticated level sensor, temperature sensors and pressure sensor, this system will able to give better accuracy on term of control technology.

ACKNOWLEDGEMENTS

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