Design, Modelling and Application of Microcontroller (MCU) on Marine Heat Exchanger

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ABSTRACT

One of the most vital system onboard is the sea water cooling system. Main engines as example are designed to operate continuously on long hours which contribute to energy loss in form of heat. This heat energy loss is to be reduce or carried away by a cooling media otherwise the main engine will become malfunction or breakdown. Two major well known cooling system practically used onboard are fresh water system and sea water cooling system [1]. For a Dredger ship, the most common problem is the high temperature for the main engine HT circuit. During dredging operation, HT temperature is rising and although the 3-way valve actuator operate to fully open so that HT fresh water will not bypass meaning to enter the heat exchanger (cooling by sea water), HT temperature is still maintained and not reduce which trigger the HT high temperature alarm. This effect is common due to the nature of dredging operation itself near port or shallow waters. In shallow waters, sea water as the cooling media for HT heat exchanger comes with natural debris such as sand, mud, mussels, leaves and seaweed. Furthermore, in certain port, human debris also contribute such as garbage and plastic bags. These debris will accumulate which result in reduce of sea water flow and lower the efficiency of heat exchanger. The only thing engine crew can do to recover is to manually backflush/backwash HT heat exchanger. Hence the main objective of this project is to improve the current system by an applicable design using microcontrollers unit (MCU) based system.

KEY WORDS: *PIC microcontroller, Heat exchanger, MCU*

NOMENCLATURE

CPU	*Central Processing Unit*
HT	*High Temperature*
LED	*Light Emitting Diode*
MCU	*Microcontrollers*
PIC	*Peripheral Interface Controller*
RISC	*Reduced Instruction Set Computing*
R&D	*Research and Development*
TSHD	*Trailing Suction Hopper Dredger*
UMS	*Unattended Machinery Space*

1.0 INTRODUCTION

This design was particularly chosen and offer to improve automation systems onboard dredger while ease the task of engine crews in case of shortage. It is simulated using the Proteus software and then later to implement and test to operate HT heat exchanger backflush actuator valve. The program has then compiled in PIC C Compilers, and were programmed into the microcontroller using a programmer for PIC 8-bit microcontrollers. The model functioned suitably by using simulator software.

1.1 Similar System

Basically, most of the ship's sea water cooling system is having manual butterfly valve attached to heat exchanger backflush line. As far as time goes and R&D move forward, the famous manufacturer ALFA LAVAL has developed a compact Automatic Backflush Valve (Figure 1) recently [2]. During normal operation, the butterfly valve directs the flow to the plate heat exchanger for normal counterflow operation. In the backflush mode, the butterfly valve turns 90 degrees to reverse the flow direction and flushes any accumulated matter to overboard. Each valve includes a control box, which can be mounted on the valve or at a remote location. New shipbuilding will have the opportunities to implement this new invention from ALFA LAVAL.

Figure 1: Automatic Backflush valve.

1.2 Current System

Main engines HT temperature automation and controls onboard dredger normally covering some basic application. For examples in Figure 2, TSHD Inai Kenanga for one main engine established two temperature transmitters (C275) for HT inlet and outlet engine and one temperature control (C276) for actuator 3-way valve (C125) with a controller located in an external control unit. There is no controller for HT heat exchanger backflush valve. It consists only two manual butterfly valves (C402 & C403) which have to operate frequently during dredging operation in shallow waters [3].

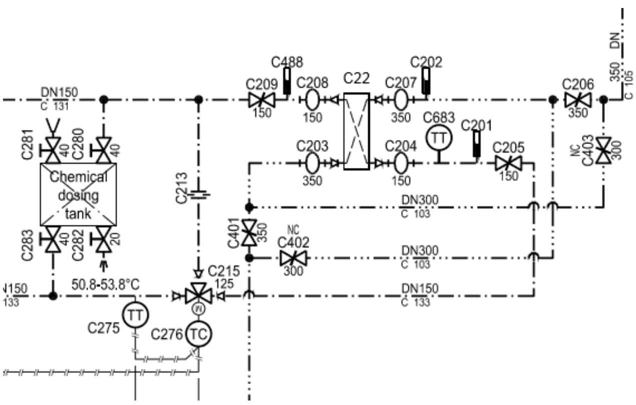

Figure 2: Cooling Water diagram

1.3 Proposed System

A modest, reliable, configurable, easy to be monitored and operated electronic control system is proposed to deliver a beneficial assistant and backing for the dredger crews.

2.0 METHODOLOGY

A Microcontroller will constantly observe the system temperature by the temperature sensor (LM35). Temperature sensor is installed on the outlet pipe of the cooler. It will be acting as the switch to complete the circuits, and eventually the MCU will then decide on the next course of action. The temperature value measured by the temperature sensor is directly displayed on the display screen (LM016L) on the panel board. The display screen is connected to MCU unit independently, in the event of failure of MCU unit for the display screen, it does not affect the function of the other MCU that control the actuator of the valves. The LEDs are connected in the system for giving the indication in which states of running system, either in normal operation or backwash operation. The system can be operated by Auto and Manual mode, it can be set by the switching method. Switches is connected through a relay, once the switched is latched, the system is in Auto mode, or vise-versa. It controlled the operation of the actuator that turn the valves to normal or backwash position. In the Manual mode, the MCU does not in action. Thus, all operation is to be controlled manually.

2.1 Component

The components of the system consist of (1) PIC16F84A [4], this Microcontroller come with only 18-pins, it is mainly use for the process. In other hand, (1) PIC16F877A [5], is used mainly for the Display screen. This Microcontroller come with 40-pins. It features 8 channels of 10-bit Analog-to-Digital (A/D) converter which interfaced with the LM35. (3) light emitting diodes (LEDs) to turn as visual response as GREEN for Auto, YELLOW for Backwash, and RED for Power. (1) LCD Display unit LM016L [6], it uses to showing the value corresponding to the value measured from LM35 (temperature sensor) unit. (1) LM35 [7], is use as a temperature sensor unit that measure the system temperature. (2) Actuator that will be activated and controlled the valve to open or shut, (1) Relay which will be used to control the switches. (2) Actuator unit to control the three-way valve. Figure 3 illustrates the schematic diagram of the system design.

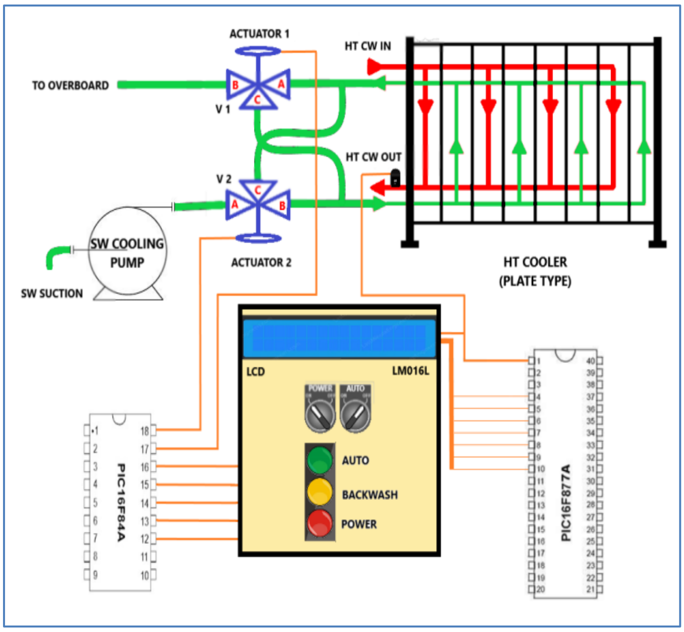

Figure 3: Simplified Schematic diagram

2.2 Operations

The operation concept is described below:

- ✧ At first, LED red is on to indicates the system Power in On.
- ✧ LED Green is on when the system is operated in AUTO mode which can be selected from the switch latching method. In Auto mode, the system is continuously measuring the system temperature, thus, controlling the operation of the actuator of the valve in order to open or close.
- ✧ In Normal operation, Actuator V1 and Actuator V2 operates the three-way valve in position A-B. This normal operation is working where the temperature is below 81℃. LED Yellow is OFF.
- ✧ If temperature rise up to 81℃ or more, the Actuator V1 and Actuator V2 is activated and moved the three-way valve to position V1=A-C and V2=B-C as refer to Figure 1, where is now in Backwash mode. LED Yellow is ON.
- ✧ Once system temperature reducing to 76℃, the Backwash mode is Off and normal operation takes place. LED Yellow is OFF.

2.3 Microcontrollers

PIC16F84A (Figure 4), is used for this system. The MCU is used as the brain of the system, it has the ability to function without other sophisticated modules to be attached. PIC is a family of reduced instruction set computing (RISC) microcontrollers manufactured by the Microchip Technology which is resultant from the PIC1650 that is formerly developed by General Instrument's Microelectronics Division. PIC is the integrated circuit which was frequently used to develop in controlling exterior devices and lightening the load from the main CPU in the system. Matched to a human being, the main CPU act as a brain and the PIC is same to our autonomic nervous system. Hence, it is recommended that 8-bit PIC16F84A microcontroller which is sufficient enough to act as the central control of the system.
Meanwhile, another MCU, PIC16F877A (Figure 5), is used in order to isolating the display screen controls thus may not affecting the process of other MCU and provide more safety to the system.

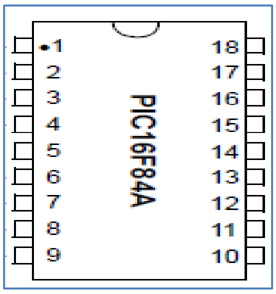

Figure 4: PIC16F84A Microcontroller Pin assignment (PDLP)

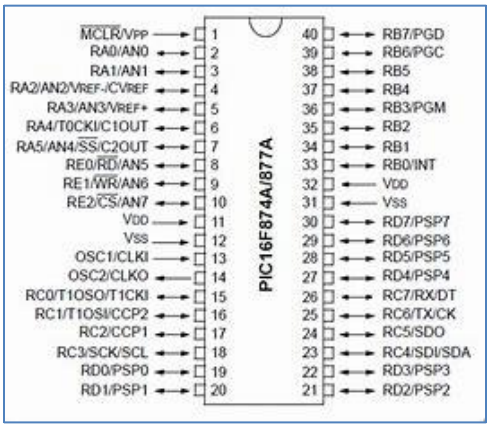

Figure 5: PIC16F877A Microcontroller pin assignment

2.4 Software

The "C compiler for the PIC MCU," is utilized for composing, editing, compiling, and programming the codes for the microcontrollers. This compiler, which empowers the microcontrollers to be customized in high level programming languages, together with PicKit2 programmer. 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 fundamental capability of the entire system is to allow a timed with micro-seconds interim, to acknowledge the sensor inputs, and to activate the outputs, either to the Display unit and the actuator to operates the three-way valves.

2.5 Programming Description

The program used to regulate the entire process is embedded in PIC16F84A and PIC16F877A microcontroller's C language. All the codes have been compiled and tested using CCS compilers.

2.6 System Flow

This system works in sensing the temperature in the outlet of the cooler into the main system, the system is continuous. The temperature sensor is attached to the outlet pipe from the HT heat exchanger, it will send the corresponding values to the Display unit on the Control panel and send the signal to the Microcontroller Unit. The MCU then will intelligently decide on the next course of action, activation the Actuator to operates the three-way valve either in normal or backflush operation depending the temperature value. If the value at 81°C or more, the backflush operation is works thus move the actuator of V1 and V2 to opens the valve in desired directions. At this moment, LED Yellow will be On. Once temperature drops to

76°C and below, the MCU then activates the operation back to the normal mode, LED Yellow then will be Off. Figure 6 below showing the system flowchart;

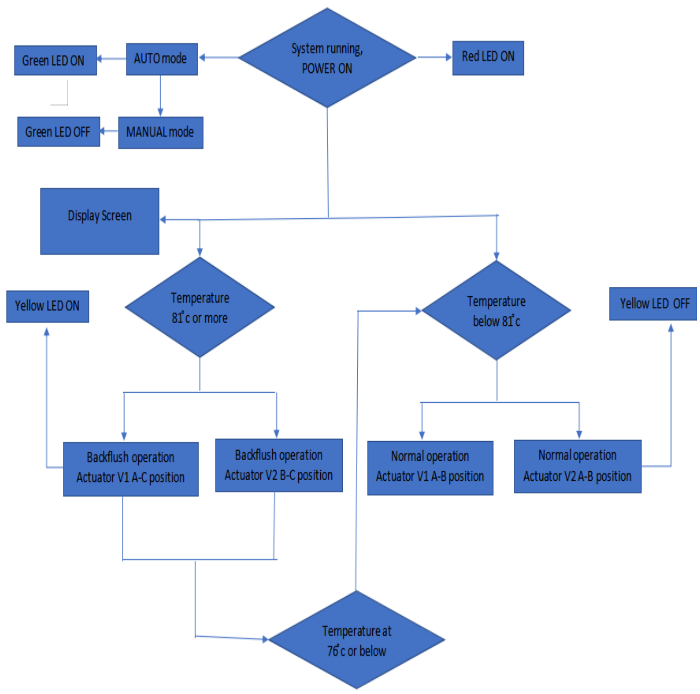

Figure 6: Flowchart of the system

2.7 Circuit

The circuit have four main elements: the power source section, microcontroller segment, which comprises the system input parts, and the output parts. All these modules are integrated to the MCU unit. Refer to the Figure 7.

Power source action will be confirmed and indicates by the LED Red On. Microcontroller segments is divided into two parts, one is mainly for the Display screen unit and one is for the operations of the Actuator. Input parts are directly connected to the LM35 unit which is the temperature sensor that measures the system temperature. The output parts receiving signal to activates switches where then operates the actuators.

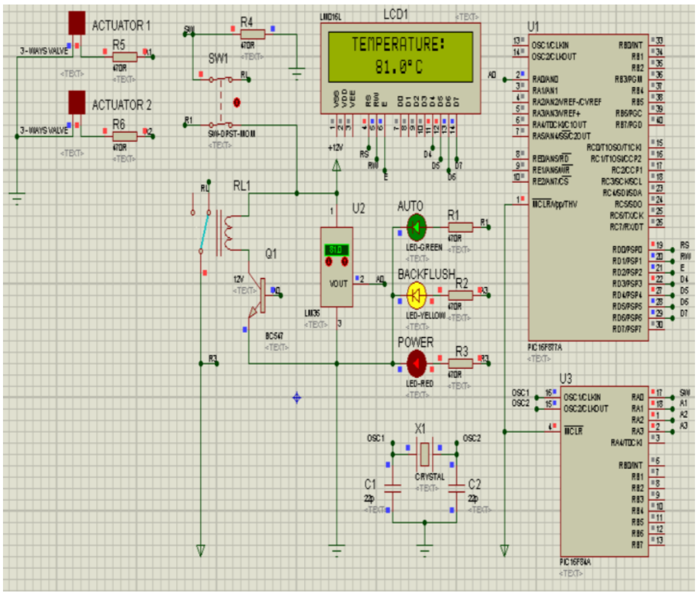

Figure 7: Circuit diagram

3.0 CIRCUIT DESIGN SIMULATION

Using the software Proteus v7.6 we have simulated the circuit for testing and try out the idea. The simulation includes the reading of various input temperature measurements from sensor, displaying the temperature and program for controlling action. The components required for HT heat exchanger backwash actuator valve consists of temperature sensor, PIC microcontroller, display module and control actuator valve unit. The components are selected from the software library and connected by continuous wire and wire label.

The assembly code programming is done on CCS C Compiler software, the developed program is installed in the PIC microcontrollers. Then the circuit was tested by increasing temperature at the sensor until the setting temperature to activate the actuator.

For PIC 16F877A microcontroller, the input from the temperature sensor was connected to RA0 pin, while the outputs of the system were connected to RD0 to RD7 for the display unit. Whereas the input of PIC16F84A from the switch 1 was connected to pin RA0 while the outputs for the actuator valve and indicator LED connected to RA1, RA2 and RA3.

4.0 RECOMMENDATIONS

This circuit can be expanded by incorporating a differential pressure sensor. The differential pressure sensor functioned for sensing the difference of cooling water pressure between inlet and outlet of the heat exchanger. Apart from the temperature sensor input, the differential pressure will help the backwashing process to be more precise and efficient.

A manual backwash switch can be connected further to control the backwash manually as well as automatically.

With this circuit, an audible alarm can be added and used effectively if the jacket temperature goes up more than the setting temperature. So, the operator is alert and able takes action to prevent any machinery failures.

5.0 CONCLUSIONS

The aim of this paper was to describe a microcontroller-based temperature control system with temperature set-point and actual temperature display. A particular design of such system has been described and verified.

The circuit can be made useful in practical area where the circuit can be connected to a device whose temperature has to be controlled at a particular limit like the HT heat exchanger backwash actuator valve.

In conclusion, the constructed microcontroller-based temperature control system circuit meets the requirements sufficiently for use in temperature control applications.

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