Proceedings of The
IEEE International Conference
on Industrial Technology, 1996

A Distributed Control System of Ship Diesels

Hui Chang－kun
East China Shipbuilding Institute
212003,Zhenjiang,Jiangsu, China

Abstract——There are several diesels installed in a big ship. In the engine room one or two diesels are used for driving the propellers and in ship power station three or more are the drive of electric generator for power supply. A very important thing is to optimize the operation process control of those diesels. This paper introduces an optimized distributed control system based on computer science, including the principle of this distributed control system,the configuration of hardware, the data communication, the software and the algorithm of control.

Key words: distributed control, communication protocol, fuzzy control.

I. The configuration of hardware

It's a well known fact that the majority of ship diesel is controlled by electro－pneumatic elements, electric devices, electronic circuits and other actuators, such as electro－magnetic valve, clutch, E/P converter and so on , But this distributed control system we developed is based on computer science.

After the consideration of the adverse environment of voyage, for example the bad jolt, the high temperature and the humidity extreme, the optimized hardware configuration we selected is as follows:

A. Master computer:

The master computer is a microcomputer with abillity of anti－severe environment and being compatible with IBM/486 .

B. Slave station:

Two programmable controller(PLC) are used as the contrl of diesels for propellers, one PLC is used for controlling three diesels of power station. Each PLC consists of rack, power supply, cpu module, input/output module and other peripheral interface modules such as:

1) Three A/D converters come into use for data acquisition of the speed of diesels and the output power of generators. Each A/D converter has four input channels and the input range is 1～5V of voltage or 4～20mA of current.

2) The outputs of three D/A converters are put into use for the control of speed or frequency. Each D/A converter has two output channels and the output range is 4～20mA current.

3) Three communication unit compatible with series CCM2 protocol should be used for data communication between the master computer and PLC.

C. Printer:

The printer we selected has a very important specification that is a build－in Chinese character base.

D. Telegraph:

The telegraph acts as the transmission of the command signals from bridge room to engine room such as "START" "FULL SPEED AHEAD"… Because this distributed control system is based on computer tecknology, we can use a special keyboard instead of traditional telegraph.

For stepless speed regulation, function key "＋", "－" must be included while the 8 speed command keys is not indispensable.

Using keyboard instead of traditional telegraph is a very important improvement for ship equipments.

0－7803－3104－4

E. Other actuators and sensors:

1) The function of E/P converter is to convert 4~20mA current to 0~6 bar pressure for adjusting the discharge of oil supply.

2) Several electro-magnetic valves are connected to diesels for executing the telegraph order of "AHEAD", "ASTERN" or "STOP".

3) Tachogenerators and frequency converters are also used as sensors.

II. The principle of this control system

Since computer science developed rapidly and was applied widely, to develop the control system of ship diesels by using computer technology is the tendency of shipbuilding industry.

Like all good ideas, the idea of using PLC as the slave station comes from to do some thing better. That some thing was the reliability of PLC is good enough for the adverse environment of voyage. As long as the PLC works the ship voyage is going on even if the master computer is out of order. Normally one PLC can control the diesel's running process automatically and independently. The master computer mainly search for informations of the working states of slave stations (read data from PLC). Only when emergency happened it might send command signal to slaver stations (write data to PLC).

The principle block diagram is shown as Fig. 1

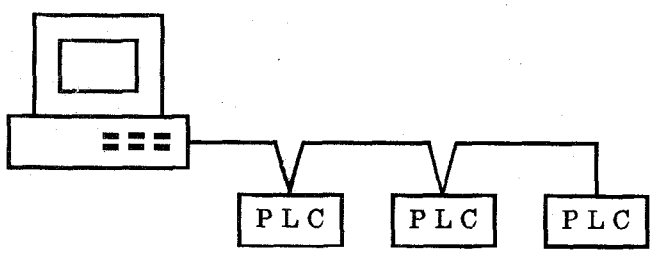

Fig 1. The Principle block diagram

The Fig. 2 shows the layout of the control of single diesel.

It is the principle structure of the master computer and one PLC. Other connections between master computer and another slave stations are some thing like Fig. 2. (only power station is a little different from this one.) The main control content are starting diesel, adjusting the speed to fit the sequence diagram of diesel and converting the direction of AHEAD, ASTERN.

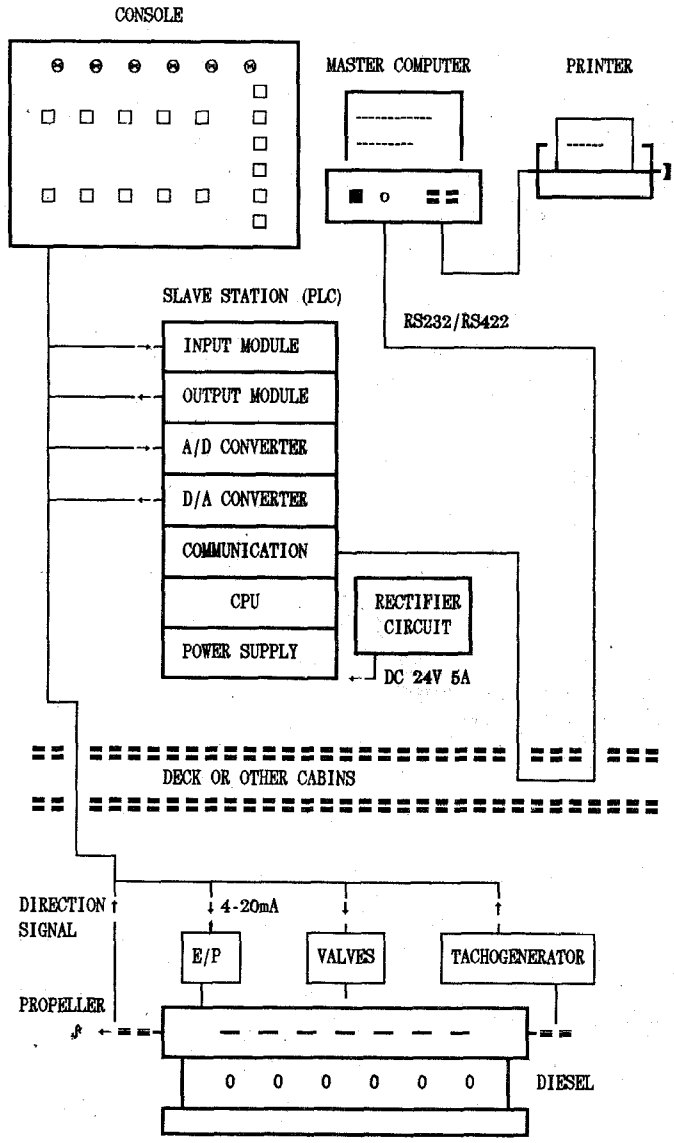

Fig 2. The layout of the control of single diesel

A. Starting diesel

Assume engine room equiped with lower speed diesel, after press a speed key (e. g. SLOW AHEAD) on console in the bridge room, PLC will

manage it according to user's program, Its logic outputs enable electromagnetic valves to adjust the flow sequence of compressed air so as to ensure the ship go "AHEAD" . Then ignite, fuel and speed up , If the speed can be more than 40 rpm in a certain time T1, the starting is successful, otherwise fail.- After three successive failures of starting were detected, PLC will send the logic signal for alarm and the try of starting will not be permitted until the equipment was repaired.

B. Adjusting speed

After the success of starting, PLC execute adjusting speed subroutine. The data acquisition of the real speed of diesel realized by means of A/D converter. PLC performs different logical operation, comparison operation and numerical calculation. Then apply the logic output signal to switch devices, electromagnetic valves, indicators, alarms and so on, apply the digit output to 7 segment display and apply the 4~20 mA analog output to E/P valve via D/A converter. E/P converts 4~20mA current to 0~6 bar pressure for cotrolling the quantity of supplied fuel so that the rotational speed of diesel can be controlled automatically.

Re the algorithm of speed regulation, a new Microcomputer Fuzzy Approximation Algorithm is introduced here briefly. As control role of this algorithm, the output of computer is expressed as : $u(k)=u(k-1)+\Delta u$, It is something like PID controller. But it is not according to digital PID method to get Δu . The Δu is got from a control table structured in the way of fuzzy controllers. As compared with common fuzzy controllers, it need not give the membership function. So, this algorithm not only avoids the difficulty of the determination of proportional, integral and derivative coefficient of PID controller but also avoids the difficulty of complicated calculations of fuzzy controllers. [1].

The algorithm is consist of 3 parts:

1) The fuzzy set of input errors

Let the required speed seleted by pressing one of the speed key of telegraph keyboard as the input set point (SP).

Definition 1: $e=SP-U_i$

$$\Delta e=e/Sp$$

$$\Delta E=\begin{cases} L, & 0.5<|\Delta e| \\ M, & 0.2<|\Delta e|<0.5 \\ S, & |\Delta e|<0.2 \end{cases}$$

Then signed fuzzy set ΔE:

$\Delta E=\{\Delta E_1(NL), \Delta E_2(NM), \Delta E_3(NS), \Delta E_4(0), \Delta E_5(PS), \Delta E_6(PM), \Delta E_7(PL)\}$

Here e=input error, L=large, M=medium, S=small, N=negative, P=positive , U_i =real speed

2) The output increment set

there should be a fuzzy set of output increment ΔU corresponding to ΔE.

$\Delta U=\{\Delta U_1(NL), \Delta U_2(NM), \Delta U_3(NS), \Delta U_4(0), \Delta U_5(PS), \Delta U_6(PM), \Delta U_7(PL)\}$

But, the analog output of computer should be a concrete number, Thus

Definition 2:

$$|\Delta u|=\begin{cases} 5, & \Delta E=L \\ 2, & \Delta E=M \\ 1, & \Delta E=S \end{cases}$$

$\Delta U=\{-5,-2,-1,0,1,2,5\}$

Here ΔU is the signed output increment numerical set.

3) The fuzzy control role

The fuzzy control role is as follows:

$$u(k)=u(k-1)+\Delta u \qquad (k=1, 2, 3\cdots\cdots)$$

The u(k), u(k—1) are the kth and (k−1)th output of computer respectively, You can get the value of Δu according to the fuzzy control table 1.

It is different from general fuzzy cotrol table because this table is not necessary to store in the memory. It is easy to express by using computer language such as "if" statement of BASIC, "switch( )" statement of C language etc. We choice a simple way to describe it:

```
if  Δe=NL  then  u=u-5
if  Δe=NM  then  u=u-2
if  Δe=NS  then  u=u-1
if  Δe=0   then  u=u
if  Δe=PS  then  u=u+1
if  Δe=PM  then  u=u+2
if  Δe=PL  then  u=u+5
```

In the beginnig of the adjustment of speed, the

speed varies in accordance with a certin slop. When the speed is near the 80% of the SP the computer executes the program of fuzzy approximation algorithm. The action of u=u+1 or u=u−1 will repeat many times alternativelly. The Δe will be smaller and smaller. That is why it is so called "approximation".[2]

Table 1. Fuzzy Control role

Δe \ Δu	−5	−2	−1	0	1	2	5
NL	1	0	0	0	0	0	0
NM	0	1	0	0	0	0	0
NS	0	0	1	0	0	0	0
O	0	0	0	1	0	0	0
PS	0	0	0	0	1	0	0
PM	0	0	0	0	0	1	0
PL	0	0	0	0	0	0	1

The control principle of ship power station is something like what we introduced hereinabove except control parameters. We no longer describe it in detail.

C. Converting AHEAD/ASTERN

If a running diesel received a command of counter direction from telegraph, PLC would decrease the speed to zero at first and then apply the logic outputs to corresponding valves to change the flow sequence of compressed air in order to ensure the ship going in required direction.

Ⅲ. The communication protocol

Up to now, there is no compatible international standard communication interface software for PLC in the world. So in order to realize the data communication between master computer and slave station PLC, users will develop the communication interface program themselves which must comply with the protocol supplied by PLC manufacturers. This control system adapts series communiation protocol shown in Fig 3.

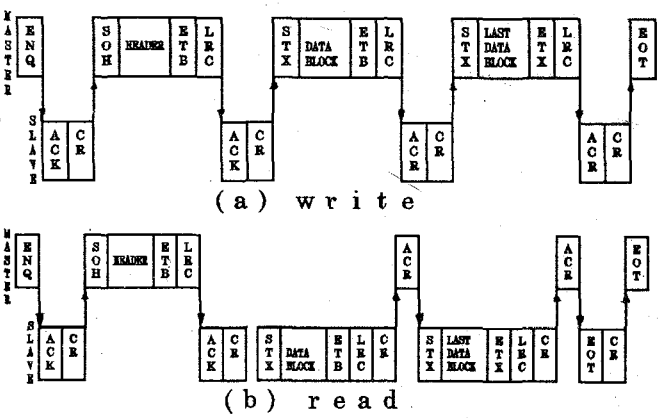

Fig 3. series communication protocol

In Fig 3.

ENQ: enquiry ,
ACK: acknowledgement, CR: return
SOH: start of header
STX: start of data block transmission
LRC: longitudinal redundancy check
HEADER'instruction transmission contents

The format of header is as follows:

SOH
slave station number
transmission direction
function
start address
transmission volume
master station number
ETB

Ⅳ. The software

The software consists of 4 structured program blocks :

A. The 4K byte PLC program or ladder diagram for controlling the diesels of propeller driving:

The function of this part of software has been described briefly in item Ⅲ before.

B. The 4K byte PLC program for controlling the diesels in power station:

Besides the general function of starting, data acquisition and processing, display and alarm, its function also includes the regulation of frequency-, the sharing of loads, the parallel connection of feed.

C. The interface program for the communication between master computer and PLC.

The user's communication interface program interruption address is INT 14H. This program normally include initial data such as baut, parity, stop bit, header structure and so on so as to meet the requirements of communication protocol.[3] It is about 700 lines program in assembly language. [4]

D. The user's interface program.

The user's interface program we developed is about 4000 lines program in C language. The contents consists of :

1) Menu: It includes main menu and each item of main menu has several sub-menu. All the functions of this distributed control system are covered in these menus.

2) Mouse & hot key: You can select what you want to display or to print by means of mouse or hot key or cursor bar.

3)Window : The contents of sub-menu are shown in different windows. Different color and different size of windows can be shown on one screen by layers.

4) Graphics:Graph mode are used to show the system principle structure diagram and other figures.

5) Chiness character:In order to meet the needs of different customer all the writing use both Chinese and English character. The Chinese characters are shown on screen based on English DOS instead of Chinese DOS. It is a very advanced technique.

6) Parameter transfer:The parameter transfer between * .asm files and * .c files (* : any file name) or between registers often happened. Some functions are helpful for the transfer, for instance, function
int sndrcv(station, baut, parity, wr, func, bytes, spd, buf)and function
int86(int intr-num, union REGS * inregs,
union REGS outregs).[5]

7) "On Line" text of 'help' : There are a lot of text in the menu of 'help'. During the emergency happens, if you want to get some directory message from the screen of computer, you can make choice of 'help' menu. But , the text is quite long. Where is the exact place? How can you find what you want quickly ? Our software offers the convenience of search. If some trouble happend the exact location of the text of 'help' corresponding to this trouble will change its display color from white to red.

Summary:

This distributed control system altered the traditional control mode of ship diesels and it has the ability of anti-adverse environment because of the usage of PLC. The technique of "on line" text offers the facility of maintenance or trouble shorting. Especially the Fuzzy Approximation Control algorithm is simple and practical. So, this control system should have good prospect of wide applications.

References:

[1] Wang xue hui, The theory and application of microcomputer fuzzy control, China Electronic Industrial Press, 1987.

[2] Hui Chang-kun, The Microcomputer Fuzzy Approximation Type Controller, Proceedings of China Control Conference, China Science and Technology Press, 1995. pp1337-1342,

[3] Hui Chang-kun, Fang Jing, The Data Communication Between IBM and Programmable Controller, Journal of East China Shipbuilding Institute, 1994(4). pp.61—66.

[4] Yao Wanshen, IBM-PC Program Design in Macro Assembly Language, The Press of Har Er Bin Industry University, China , 1992.

[5] Yuan Jiansen, C Language Pratical Technique , Beijing Teacher's University Press,1993.9