International Journal of Navigation and Port Research
Vol.30, No.4 pp. 291~294, 2006 (ISSN-1598-5725)

ICCP Control and Monitoring System for Ships

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Abstract : *Corrosion is never avoided in the use of materials with various environments. The underwater hull is normally protected against rusting by several coatings of anti-corrosive paint. The purpose of ICCP(Impressed Current Cathodic Protection) system is to eliminate the rusting or corrosion, which occurs on metal immersed in seawater. This thesis is about the ICCP control and monitoring system, which brings protection against the corrosion of the ship's hull in the sea environments. The test system for ICCP is composed of a power supply, anode, reference electrode and controller. The test system is composed power supply, anide, ref. electrode, shunt and etc. The protection current is sent to the protection area though anode. Reference electrode senses whether or not the detected potential is within a range of protection of test equipment and then it is automatically controlled to increase or decrease the amount of protective current to be sent to the anode by controller. The monitoring system with LabView is also detected in order to check the normal state of the system at operation period, because an operator does not always watch over this system and thus the system cannot operate well because of his or her negligent management. This paper was studied the variation of potential and current density with environment factors, velocity and time, and the experimental results will be explained. Also, It is suggested that this system can accommodate a ship's automation for SCMS(Ship Control and Management System) and will be very useful.*

Key words : *Environmental factor, Converter, Corrosion, Protection Potential, ICCP, Monitoring system, Velocity*

1. Introduction

ICCP System is to prevent the rusting or corrosion, which occurs on metal immersed in water. When properly installed the system in the hull will eliminate the corrosion on the hull, rudder and propeller. Corrosion protection of hull openings and recesses such as sea chests, intake and discharge ports can normally be provided to only a limited degree. It is known that the corrosion of a metal immersed into water is caused by a very small current flowing from one small area of the hull to another. The small area where the current leaves the hull and enters the water are called "anodic" while the small areas where the current enters the hull from the water are called "cathodic". Corrosion or rust occurs only at the anodic areas.

When the anode current is increased, the protection given to hull is increased and corrosion is reduced. Also, the voltage between the reference electrode or cell and the hull gradually increases. Excessive anode current higher than optimum reference electrode potential provides no further reduction in corrosion and wastes power. Excessive reference potential of reference electrode may even cause paint damage.

There are five components required in the basic ICCP system as a reference electrode, ship's hull, anode, controller and power supply unit. The system is designed to be operated automatically and to require a minimum amount of maintenance. The controller should always be in automatic with ICCP control program and power circuit. The controller has function as a voltage and current limiting. In the event that one or more anodes have failed, the current limit is used to prevent the remaining anodes from drawing excessive current. Output voltage will increase as the need for protective current increases. To drive more current through the anodes a higher voltage will be required. The power is controlled in the converter section and is distributed to the anodes from where it flows through the surrounding seawater to return through the hull. ICCP operation condition is varied with Ph, temperature, velocity, etc.

This paper presents a new PWM converter and monitoring system for ICCP. Control computations and PWM generation can be carried out using a microprocessor with minimal external hardware. The monitoring system for ICCP is designed with several sub-areas and is displayed the potential and protection current with reference electrode and anode power.

2. PWM Converter

The power converter for ICCP system is supplied with AC power from the ship's electrical system. This AC

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power is rectified in the PWM converter section and distributed to the anodes. Schematic diagram for ICCP system of ship is shown in Fig. 1.

In Fig. 1, the converter system uses six switches that are capable of conducting current in both directions. The switches operate in the continuous conduction mode and are turned on and off, therefore the output DC voltage is never shorted.

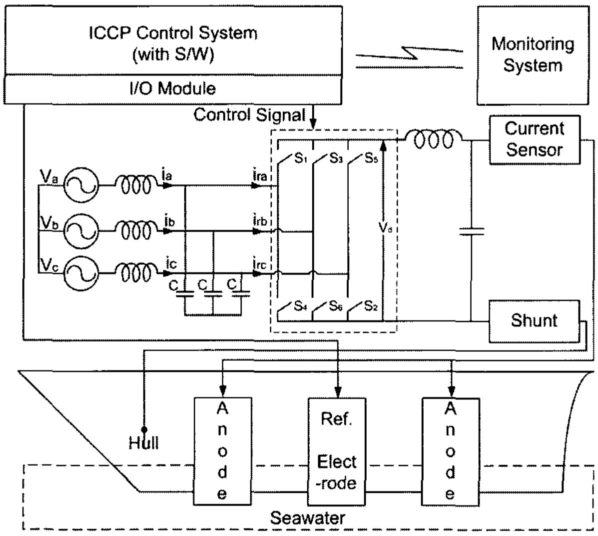

Fig. 1 Schematic diagram for ICCP system

The voltage space vector v and the current space vector i of the PWM converter in Fig. 1 is expressed by

$$v = V_m e^{j\omega t}$$
$$i = mIe^{j(\omega t - \theta)} \qquad (1)$$

Where, θ is the phase difference to the voltage space vector v.

The output voltage V_d of the PWM converter is obtained by

$$V_d = \frac{3}{2} m \sqrt{V_m^{\ 2} + \omega^2 L^2 I_m^{\ 2}} \cos(\theta + \phi) \qquad (2)$$

Where m, V_m, ω, L and I_m are the modulation index, peak-to-peak phase voltage, angular frequency of the power source, inductor and maximum current. In the case that ϕ is given by, $\phi = \tan^{-1} * \omega L I_m / V_m$.

The dc output voltage of the PWM is affected by m, θ and ϕ. The maximum output voltage of converter can be obtained with $m = 1$ and $\theta = -\phi$. The output voltage is decreased with the increased firing angle.

3. Monitoring System

In the period immediately subsequent to the application of the coating, there is very little demand on the protection current with ICCP. During the operational life of the ship, the coating deteriorates and the demand on the protection current increases.

The underwater area of ship is a large complex cathode with at least three components such as painted steel, bare steel, and NAB(nickel-aluminum bronze). These have different current density requirements for achieving the polarization and respond differently to changes in operational conditions, particularly seawater flow. Also, this paper describes a monitoring strategy for the effect of reference electrode location on potential distribution on a test system in both static and rotation conditions in Fig. 2.

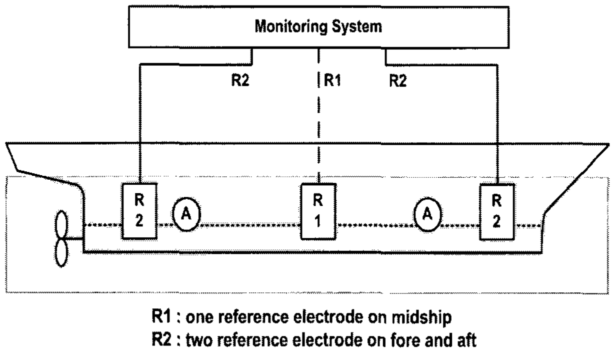

Fig. 2 Schematic of reference electrode location on ship hull

The control system for ICCP enables an unlimited number of power controller (converter, rectifier etc) located anywhere, to be operated by a main control system. It is designed with several modes. Double clicking the mode icon will open a new window with more detail information and graphics. Green icons indicate normal condition, red icons indicate alarm condition and yellow icons indicate the alarms have been acknowledged. Displayed process pictures are related to the picture plane in Fig. 3.

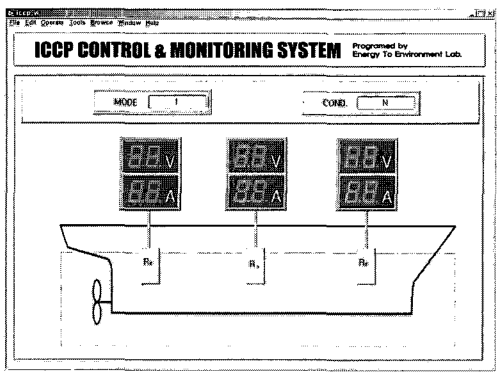

Fig. 3 Monitor picture

4. Experimental Investigation

Fig. 4 shows the flow chart for LabView monitor system. The current and potential measured at stagnant conditions in Fig. 4. The rotation speed can be controlled from 0.1 to 3 m/sec with control motor. The input voltage of anode is controlled between DC 12V to DC 38V by converter. The output voltage of converter is kept 24 V in this experiment.

The test system was implemented with the proposed control algorithm in the laboratory using anode, reference electrode, shunt, and converter.

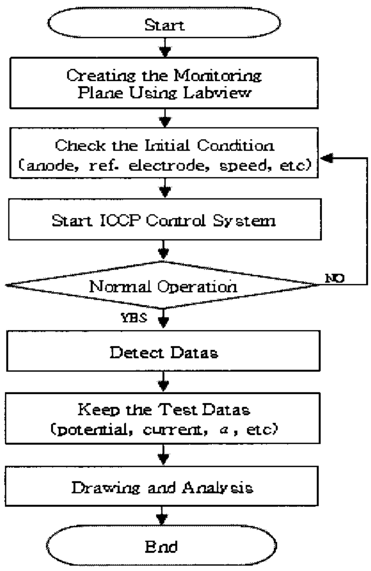

Fig. 4 Flow chart for monitor system using LabView

The monitor program is detected the control results of ICCP control system. We use this program for analyzing the variation of potential and current density with environment factors, velocity and time.

The risk of overprotection is eliminated by controlling DC current density lower than 300 mA/m^2. The conventional type of the instrument used for the periodic CP (Cathodic Protection) inspection can measure potential. Potential should be measured periodically to obtain indications of electrical contacts or interference with other metallic structures. This potential is calculated as the average of potential data of each sampling cycle. Also, current is measured for setting time at the predetermined frequency with potential measurement.

The protection current is kept with firing angle(α) of converter in ICCP. The variation of potential, current density and α with time is shown in Fig. 5. The current density was about 100 mA/m^2 after 5 minutes. The protection potential was controlled with α to keep -800mV.

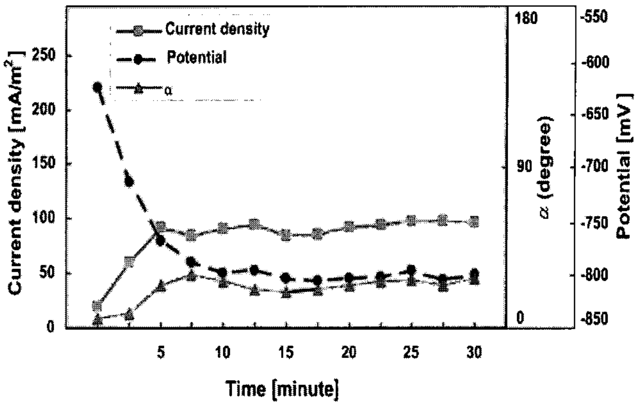

Fig. 5 Variation of potential, current density and α with time

The protection potential was maintained about -800mV after 10 minutes. The difference of potential, current density and α has been reduced after 10 minutes.

The monitoring system displayed the measurement of potential and current in Fig. 6. This figure shows the variation of potential and current with time. After 60sec, the potential value to -800mV, and the current density decreased to 200mA.

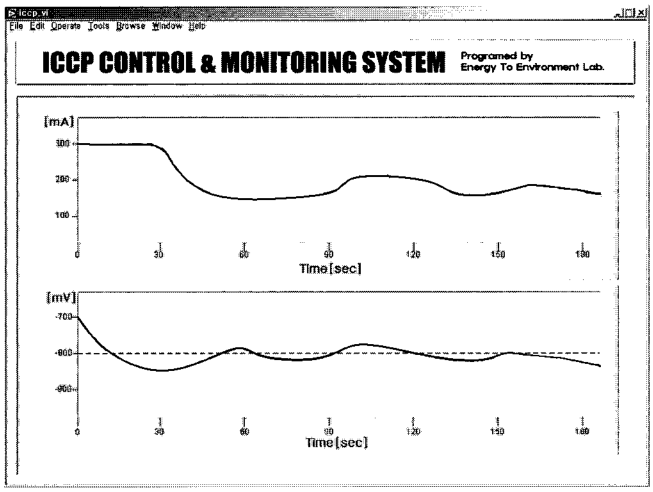

Fig. 6 Waveforms of potential and current (on/off) ($0<\alpha<90$)

In Fig. 7, the data measured for 15minutes is displayed. The amplitude of potential and current depended on the anode power. The current density decreased and potential increased according to time. The time is adjusted with α.

Fig. 8 demonstrates the effect of reference electrode location on potential distribution with static and flow conditions. In the ship, ICCP was found unable to provide the required potential at the stern and bow with one reference electrode. This shows the influence of the reference electrode position for the effective operation of ICCP.

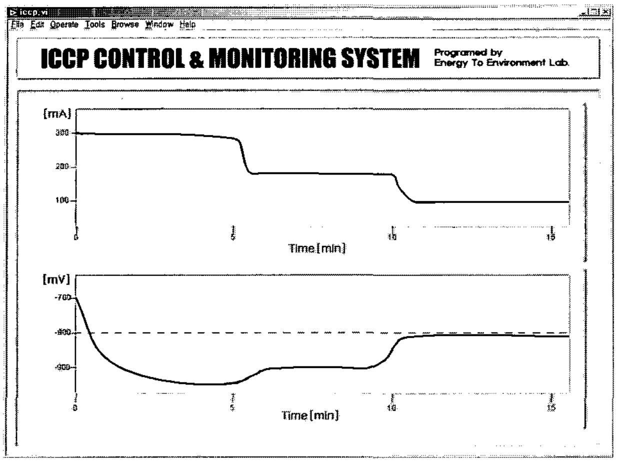

Fig. 7 Potential and current (90< α <180)
(for 15 minutes continuously)

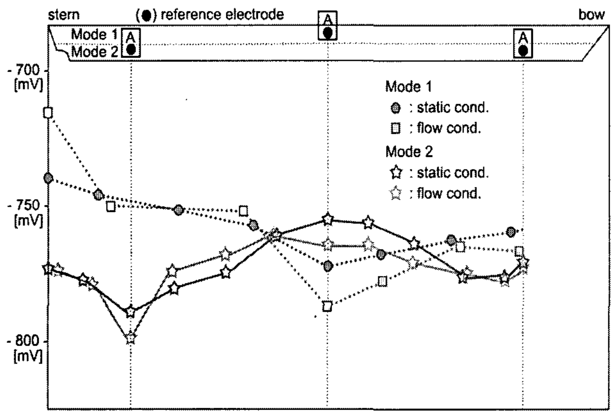

Fig. 8 Effect of reference electrode location

5. Summary

This paper describes the influence of design factors for ICCP through the experiments and output performance of converter in accordance with the firing angle. The control and monitoring system with LabView may be designed with main and sub picture plane in accordance with modes. Also, the LabView monitoring system is very useful system for SCMS.

In the simulation results with ref. electrode, the ICCP system was found unable to provide the required potential with one reference electrode on midship. Good protection levels were obtained over the whole of model with two reference electrode, under both static and dynamic conditions. This demonstrates the critical nature of the electrode and anode position to the effective operation of the ICCP system.

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Received 8 March 2006
Accepted 8 April 2006