ISSN: 2414-1895 DOI: 10.6919/ICJE.202003_6(3).0026

Fuzzy PID Control of Offshore Platform Multi-point Mooringsystem

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Abstract

Withthreemodelanchors and one real anchor to simulate the positioning equipment of semi-submersible unit, it establishes the dynamic models of anchor and anchor chain as well as the platform system mathematic model. Automatic positioning algorithm is used to control the unit move. The application of convert, PLC and industrial Ethernet technology improves the automatic level, work effect and reliability, which is significant to domestic development of semi-submersible unit.

Keywords

Semi-submersibleunit; Mooringpositioning; Anchor; Convert control; PLC control.

1. Introduction

With the improvement of the degree of automation of offshore platforms and ships, the importance of multi-point mooring control system is becoming more and more obvious. To improve the safety and stability of multi-point mooring system will bring great impact to the Marine industry.The research significance of the multi-point mooring system in this paper is as follows: improve the degree of ship automation, reduce the workload of crew and improve work efficiency;Youcan;It can greatly improve the stability of floating offshore platform, reduce or avoid the occurrence of maritime accidents, and ensure the safety of crew life and property to a greater extent.Compared with dynamic positioning, multi-point mooring has simple structure, lower manufacturing cost and relatively simple control system algorithm, both of which can well resist severe sea conditions. The multi-point mooring system is applicable to the water depth of less than 1500m and has wider applicability. Therefore, it is of great practical engineering significance to intensify the research on the control system of multi-point mooringanchorandwinch[1].

The multi-point mooring frequency conversion control system directly controls the speed of the windlass and the tension of the anchor line by controlling the torque of the windlass.Its characteristic is the control response is fast, all USES the electric signal transmission, directly controls the motor, speeds up the control windlass speed;It can realize stepless speed regulation.Compared with the hydraulic control system, the frequency conversion control system takes up less space, the control is more simple;High degree of automation;High control efficiency.The main components of multi-point mooring frequency conversion control system are: frequency conversion control system, hydraulic control system, PLC, tension sensor, encoder and other testing equipment.The multi-point mooring control system of an exploration platform is used to control the 12 cable windlass.Twelve anchor machine distribution in the four corners of each corner has a control room, control room beside the work station, there were three machine beside each machine work station an anchor winch, corresponding control communication system will work for each anchor winch and the working parameters to the centralized control room, to control all the anchor winch ecr can and working state parameters of the real-time monitoring.The variable frequency motor is the driving mechanism of the

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windlass, the hydraulic cylinder controls the high and low speed braking of the windlass, and the PLC realizes all the logic control and linkage control of the windlass.The tension sensor can monitor the mooring tension in real time, and the encoder can detect the speed of the variable frequency motor and the length of the anchor chain[2].

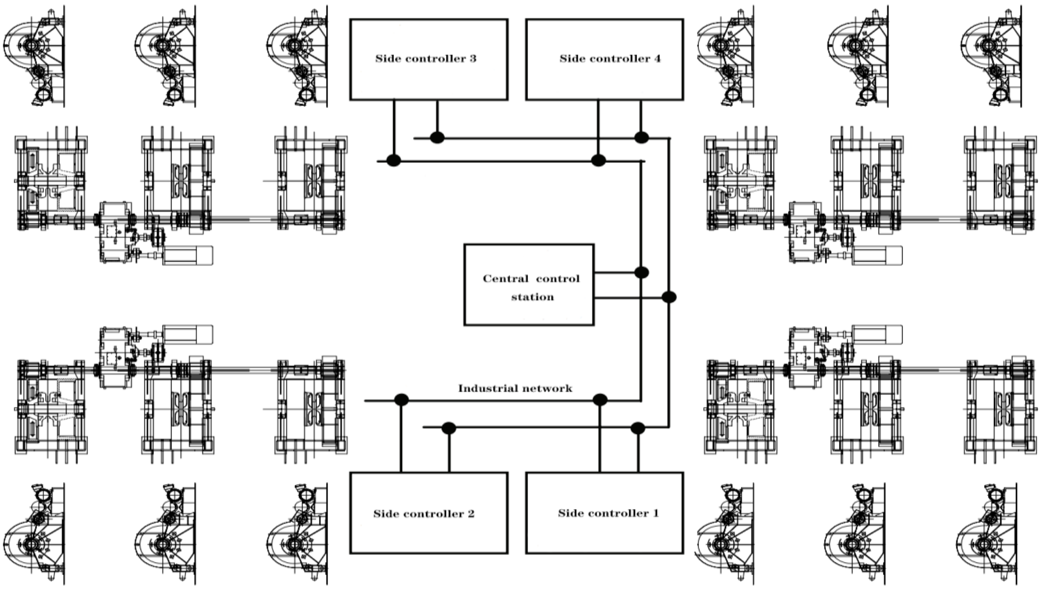

Fig. 1Flowchart of multi-point mooring system

2. Modeling of multi-point mooring system

2.1 The mooringsystem

automatic positioning test system consists of three windlass mathematical models of the platform, one physical windlass and auxiliary control system, platform motion mathematical model, and environmental load signal simulation generator, which is applied to the test system of semi-submersible platform.According to the output of the above model, the signal of the positioning algorithm controller is output to the PLC system, and then 3 analog windlass and 1 physical windlass are run, so that the platform maintains the predetermined heading and position.2.1 anchor chain cable dynamic model the dynamic characteristics of anchor chain cable have a significant impact on the motion response of offshore platform system in large water depth, which becomes more significant with the increase of water depth.The cable has the dynamic characteristics of the flexible member, and its dynamic model is uncertain and nonlinear.Accurate estimation of the dynamic characteristics of cable tension variation is a key in platform design, which can guide the design, safety and operation of platform mooring system.The dynamic equations of anchor chains are derived by using the three-dimensional elastic rod theory which is influenced by the non-linear properties of materials.The control equation of anchor cable can be written as:

$$M\ddot{r} + (Br'')'' - (\lambda r')' = q \tag{1}$$

$$\frac{1}{2}(r' \cdot r' - 1) - \frac{T}{EA} = 0 \tag{2}$$

Where, M is the mass matrix;B is the bending stiffness of the chain cable;λIs the effective tension of the chain cable;r′ prime is the first derivative with respect to s;When the curvature of the elastic rod is assumed to be small, $\lambda = T$；EA is the axial stiffness of the chain cable;q is the force per unit length of the chain[3].

2.2 Mechanicalmodelofanchor maneuver

Based on the principle of moment balance and the real-time variation of the anchor sprocket radius and angular velocity, the dynamic moment balance equation of the anchor is established, and the coulomb friction torque, viscous friction torque and dry friction torque are also considered.On this

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basis, by using the analysis method of control theory and ignoring the instantaneous changes of dry friction and moment of inertia, the moment balance equation is simplified reasonably, and the controllable mathematical model of windlass is obtained as

$$M_t - TR = J\ddot{\theta}(t) + B_m\dot{\theta}(t) + M_f + M_o \quad (3)$$

Where, R is the radius of the warping drum;J is the moment of inertia of anchor chain wheel; $\ddot{\theta}(t)$ is the rotation Angle of the anchor chain wheel; B_m is the viscous resistance coefficient of anchor chain wheel movement; M_t is the output torque of the motor acting on the anchor chain wheel; M_f and M_o are respectively viscous friction torque and dry friction torque[4].

2.3 Electromechanicaldynamicmodel

By setting up the kinematics model and motor model of each unit of the gearbox, the torque vector of the motor, the matrix of each unit of the gearbox and the excitation force vector of the gearbox can be obtained. By using these known quantities, the system composed of the gearbox of the motor can be integrated.Thus, the coupling dynamic model of anchor electromechanical machine and gear box isobtainedasfollows:

$$M\ddot{X}(t) + C\dot{X}(t) + KX(t) = F(t) \quad (4)$$

The windlassmass, system damping coefficient and system transfer stiffness are brought into the model, and the transfer function is converted into[5]:

$$G(s)= \frac{s+8.16}{s^2+8.16s+6.57*10^{-4}} \quad (5)$$

2.4 Mathematicalmodelofplatform system

Dynamic model based on the analysis of the chain, considering the complex sea condition, the motion equation of wave and current, and downwind deepwater semi-submersible platform motion law, establish a platform motion mathematical model of anchoring positioning system, and simplify the model into the bank, get the exercise for anchorage control model, the model based on to determine the reasonable control algorithm, in order to improve the anchoring positioning accuracy.The movement of the platform at sea is caused by the combined action of wind, current, first-order wave force, second-order wave force and thruster thrust.The first-order wave force has a large amplitude, which cannot be balanced by the thrust system[6]. At the same time, the high-frequency motion is only shown as periodic oscillation and will not result in the change of average positioning. Therefore, in order to avoid the wear loss and energy consumption of anchor chain in the automatic mooring positioning, only the high-frequency motion is ignored for the control of low-frequency motion.The nonlinear coupled low-frequency motion equation of the semi-submersible platform with automatic positioning of windlass in the motion coordinate system in the direction of longitudinal, transverse and sway is as follows:

$$\dot{\eta} = R(\psi)\nu \quad (6)$$

$$W\dot{\nu} + D\nu = \tau + R^T(\psi)b \quad (7)$$

3. Mooring controlsystem design

Floating offshore platform on the sea runs, time affected by rough weather, may occur large Angle offset, lead to a side mooring lines in a tight state, plus the mooring line has been in the water of the sea, part of the mooring line will be aging, in this case if artificial operation can't adjust in time, may lead to the anchor line rupture, floating offshore platform to get rid of the mooring line, thereby causing loss to the life and property, etc.When floating offshore platform is the external environment monitoring to tension values transmitted to the monitoring system, through the signal processing in the transmission to the ecr controller, the controller then compares and analyses the monitoring signal and set point and the output control signal to adjust anchor mechanical and electrical machine parameters, when outside the range value chain tension, windlass release chain, avoid chain break off because of the force is too large[7].The principle of mooring control system is shown in figure 2.

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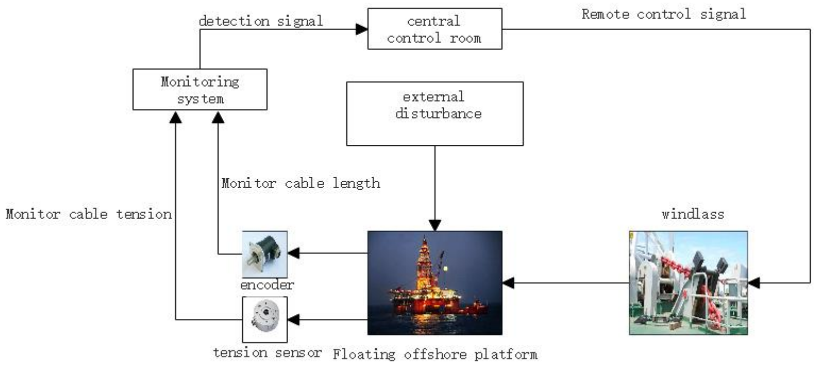

Fig. 2 Schematic diagram of mooring control system

Fuzzy-PID controlmethodis applied to the mooring control system of floating offshore platform, so that the mooring control system can adjust and release the mooring line according to the variation of anchor line tension, control the tension within a certain range, and realize the goal of tension control of windlass system.

3.1 Design offuzzy PID controller for anchor winch control system

In actual industrial control, the internal structure and control parameters of the controlled object may change due to the influence of external environmental disturbance factors, although adaptive control has the ability to automatically generate new control strategies based on external environmental disturbance.However, the adaptive control performance can not be effectively guaranteed, and stability control may not be realized in the case of nonlinear systems that are difficult to solve.With the development of control technology, people put the experience of adjusting PID parameters into the computer system, and then the computer set the PID parameters according to the needs of the control system.The combination of expert control and classical PID control can achieve better control effect.But before the control parameters into the classical PID control, still need accurate control parameters, so the experience and knowledge of technical personnel is generally fuzzy processing, after fuzzy control to get accurate control parameters.In order to solve a series of problems that technical personnel can not accurately transfer the empirical control parameters directly to the controller and some parameters in the control system can not be represented by constants, fuzzy theory establishes fuzzy rules, makes fuzzy reasoning and decision-making, and then obtains accurate PID control parameters by solving the fuzzy[8].

The fuzzy PID controller receives the deviation e detected by the mooring system and the deviation change rate ec signal, and carries out fuzzy reasoning on it.The ratio, integral and differential parameters can be obtained through fuzzy reasoning, and the PID controller will adjust itself according to the three parameters obtained through fuzzy reasoning, so as to achieve good control effect and ensure the controlled object works normally.

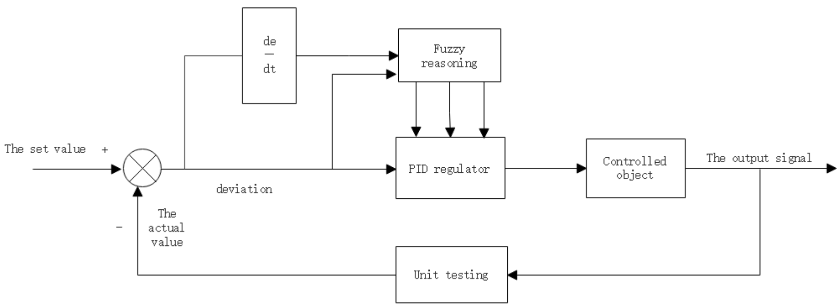

Fig. 3 Fuzzy PID control schematic diagram

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As shown in figure 3, Fuzzy reasoning module and classical PID control module constitute a subject of Fuzzy-PID control.The relationship between the three coefficients of proportion, integral and differential and the change rate of deviation is found out by fuzzy reasoning decision, and the above three coefficients are continuously optimized by applying the principle of fuzzy control to meet the needs of system control, so that the system can achieve good control effect

3.2 Fuzzy PID controlparameter setting

In MATLAB, two input and three output modes are generally adopted in the design of Fuzzy-PID controller. The input of the controller is the system's deviation e and deviation rate ec. The three parameters of proportion, integral and differential after the optimization of the Fuzzy controller are used as the input of the subsequent classical PID.Set the fuzzy subsets {NB,NM,NS,Z,PS,PM,PB} for the above two inputs and three outputs, and then set the range of field values according to the actual engineering application.

The Fuzzy controller will use the Fuzzy matrix table built by the Fuzzy rule table to accurately find the modified parameters and obtain the new parameters:

$$k_p = k_{p_o} + \Delta k_p \tag{8}$$

$$k_i = k_{i_o} + \Delta k_i \tag{9}$$

$$k_d = k_{d_o} + \Delta k_d \tag{10}$$

where, $k_{p_o}, k_{i_o}, k_{d_o}$is the design value of classical PID calculated byparametersettingmethod,

$\Delta k_p, \Delta k_i, \Delta k_d$is the output signal of Fuzzy-PID controller after Fuzzy processing, k_p, k_i, k_d is the value of three PID parameters adjusted by fuzzy control.The automatic correction process of fuzzy PID control is shown in figure 4[9].

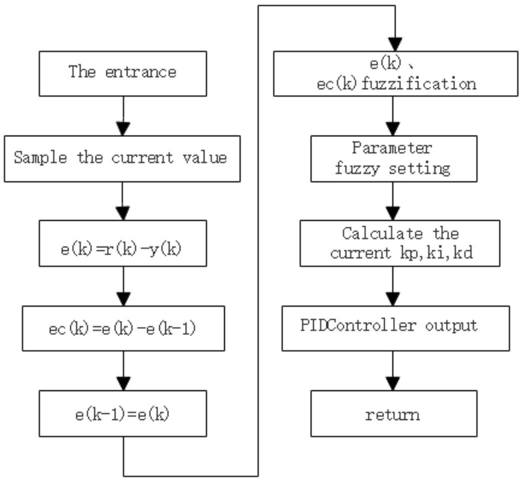

Fig. 4 Fuzzy PID automatic correction flow chart

3.3 Controller design

PID control and Fuzzy control technology has been well developed in the industrial field, engineers found that by combining the advantages of PID control and Fuzzy control technology together can get faster response, better stability of Fuzzy-PID control technology.In fuzzy-pid controller design, the Fuzzy controller is two inputs and three outputs. The three outputs correspond to the ratio, integral and differential coefficients of the PID controller respectively, and the above three coefficients are adjusted to achieve the best control effect.The Fuzzy controller design steps in fuzzy-pid controller design are the same, in which two additional output items need to be added and Fuzzy rules need to be established according to the multi-point mooring principle.

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where k_p, k_i, k_d are set as [-3,3], [-3,3] and [-3,3], respectively.

Table 1 k_p Table of fuzzy rules

e	ec						
	NB	NM	NS	ZE	PS	PM	PB
NB	PB	PB	PM	PM	PS	ZE	ZE
NM	PB	PB	PM	PS	PS	ZE	NS
NS	PM	PM	PM	PS	ZE	NS	NS
ZE	PM	PM	PS	ZE	NS	NM	NM
PS	PS	PS	ZE	NS	NS	NM	NM
PM	PS	ZE	NS	NM	NM	NM	NB
PB	ZE	ZE	NM	NM	NM	NB	NB

Table 2 k_i Table of fuzzy rules

e	ec						
	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NM	NM	NS	ZE	ZE
NM	NB	NB	NM	NS	NS	ZE	ZE
NS	NB	NM	NS	NS	ZE	PS	PS
ZE	NM	NM	NS	ZE	PS	PM	PM
PS	NM	NS	ZE	PS	PS	PM	PB
PM	ZE	ZE	PS	PS	PM	PB	PB

Table 3 k_d Table of fuzzy rules

e	ec						
	NB	NM	NS	ZE	PS	PM	PB
NB	PS	NS	NB	NB	NB	NM	PS
NM	PS	NS	NB	NM	NM	NS	ZE
NS	ZE	NS	NM	NM	NS	NS	ZE
ZE	ZE	NS	NS	NS	NS	NS	ZE
PS	ZE	ZE	ZE	ZE	ZE	ZE	ZE
PM	PB	NS	PS	PS	PS	PS	PB
PB	PB	PM	PM	PM	PS	PS	PB

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4. Conclusion

Compared with other control methods, the Fuzzy-PID control system has better stability and almost no overshoot.Besides, it has the rapidity of PID control system, the function of eliminating oscillation and steady-state error of Fuzzy control system, and the ability to resist the interference of external environment.Therefore, fuzzy-pid control is the best design scheme to realize tension control of multi-point mooring control system.

References

[1] Banik AK,Datta TK.Responseandstabilityoftwo-point mooringsystemunderrandomwaves[J].Marine Systems&Ocean Technology,2017,12(1):29-37.

[2] Gottlieb O,YimS C S.Nonlinearoscillations,bifurcationsandchaos in a multi-point mooringsystemwith a geometricnonlinearity[J].Applied Ocean Research,1992,14(4):241-257.

[3] Hsu W T,Thiagarajan K P,ManuelL.Extremenmooringtensions due tosnaploads on a floating offshore wind turbinesystem[J].Marine Structures,2017,55:182-199.

[4] Hong S,LeeI,Park S H,etal.An experimental studyoftheeffectofmooringsystems on thedynamicsof a SPAR buoy-type floating offshore wind turbine[J].International Journal ofNavalArchitecture&Ocean Engineering,2015,7(3):559-579.

[5] RudmanM,Cleary P W.Theinfluenceofmooringsystem in roguewaveimpact on an offshore platform[J]. Ocean Engineering,2016,115:168-181.

[6] Beckman W C.R/V Vema,deep-seawinch[J].DeepSea Reserch,1960,7(1):48,IN3,49-48,IN3,52.

[7] Mitchell M R,Dessureault J G.A constanttensionwinch:Designandtestof a simple passive system[J].Ocean Engineering,1992,19(5):489-496.

[8] Lincoln J M,Lucas D L,Mckibbin R W,etal.Reducing Commercial Fishing Deck Hazardswith Engineering Solutions forWinch Design[J].Journal ofSafety Research,2008,39(2):231.

[9] Alan Hendrickson,Colin Buckhurst.Chapter30-Winches[J].Mechanical Design forthe Stage,2007:341-358.