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Design of Automatic Sluice Gate Using Level Control

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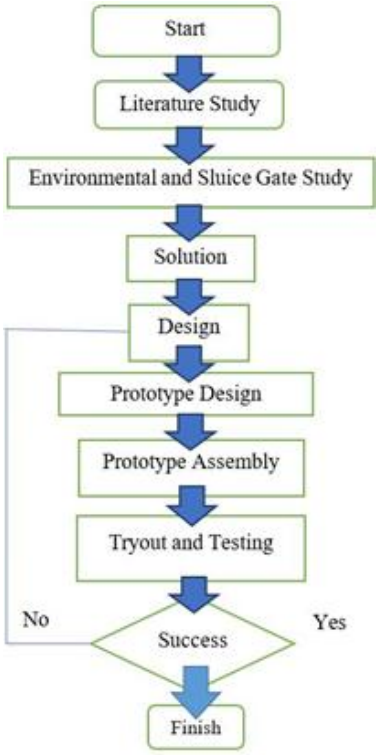
Abstract

Jayakarta Sluice Gate is located in Jakarta, the capital city of Indonesia. The setting of the sluice gate is done manually with four people. In this paper, a height automatic system is designed to set a certain height by using level sensor, PLC, and a three phase actuator with its transmission gear box. Actuator prototype is made by adjusting the component limit. The result of the prototype is in the form of a sluice gate that uses an automatic system. With a selected concept namely, ultrasonic level sensor, three phase actuator motor, and PLC control system, can control the system automatically and only need one person to take care of the system.

Keyword: ultrasonic level sensor, actuator motor, PLC, automatic

INTRODUCTION

Jakarta, the capital of Indonesia, passed by many rivers that each of them needs a sluice gate. In this condition where each sluice gate is being operated manually which is very ineffective, creates several disadvantages. For example the Jayakarta Sluice Gate, needs advancement in its operating. Deficiencies that are caused, can be minimized with the help of an automatic sluice gate drive system. The design itself works carried out by AC motors (3 Phase; 50Hz; 380V), based on a water level parameter using an ultrasonic level meter, and the command that instructs the motor to work in opening and closing the sluice is done by Programming Logic Control (PLC) system. Through this design and research, it is expected to become a reference for construction of other sluice gates with hopes that it is going to improve human resources and certainly help government agencies to reduce one of the causes of flooding.



MATERIAL

Actuator type : multiturn; type : SA[1]

Gearbox type : multiturn; type : GK[2]

Ultrasonic Level[3]

Touch panel 12 inch[4]

PLC type : FL 10[5]

Power cable type: armored; type: NYRGBY

Control cable type: armored; type: N2XRGBY

Communication cable from PLC to touch panel

Laptop

Download Cable drives program from laptop to PLC

Download Cable drives program from laptop to touch panel

METHOD

Control Method[5]

The output is in a contact to the motor (actuator), from input level of water level that is changed in a 4-20 mA control signal (analog signal) in which the input water level is processed in logic control, determining maximum set point level to signal output in contact open or contact close (NO or NC). If water level reaches the maximum specified limit then the control of touch panel will instruct drive motor to turn the motor in counter clockwise rotation (towards the open position). If water level reaches the specified minimum limit, the control of

touch panel will instruct motor drive to turn the motor in clockwise rotation (towards the close position).

Drive Motor System Method (Actuator)[1]

This drive motor method uses AC current with a voltage of 380 V and a frequency of 50 Hz (in accordance with current standards from PLN). The method of this motor drive is equipped with a control device in an open limit switch, close limit switch, open torque, close torque, blinker transmitter, position feedback, transmitter 4-20 mA, motor thermistor, reduction gear (worm shaft and worm wheel), planetary gear, integral starter and hand wheel. This integral starter includes interface board, logic board, power supply board, relay board and contactor (for forward and reverse).

Sensor Level Method[3]

This method uses ultrasonic level, the method of working system is non-contact with water level, in which water level signal is converted into a control current of 4-20 mA.

RESULT AND DISCUSSION

Product design specification

1. This sluice gate is able to regulate the flow rate of water that will pass through the Jayakarta sluice so that the flow distribution remains stable.
2. This automatic sluice gate will be able to open floodgates that weigh up to 3 tons with only a short time. for the opening of a 1-meter-high sluice gate the use of automatic design takes 3 minutes which previously takes 45 minutes.
3. The use of modern drive and sensor technology can minimize human error in regulating the opening of sluices. Previously the Jayakarta water door used manual opening using 3 people.
4. The advantage of the driving motor that is used for this sluice is when there is a power outage, the sluice gate can still be opened by turning the manual lever on the drive motor.
5. The control system can be seen directly on the monitor HMI (Human Machine Interface) so damages and system errors can be detected directly.
6. Only one person is needed to care for the system.

Conceptual design

No	Sub-Function	Principle of Solution		
		A	B	C
1	Sluice Gate Vertical		-	-
2	Motor Actuator	 3-Phase Two Wire System Motor[1]	 3-Phase Hard Wire System	-
3	Level Control	 Ultrasonic Sensor[3]	 Displacer Sensor	 Level Switch Sensor
4	System Controller	PLC System[5]	Single Loop Control System	Mechanical System

Sub function 1: Sluice Gate

The sluice gate vertical have 2 m length, 1.5 m width, 3m height. It uses structure steel as the material. Basically, the sluice gate is a sluice gate that has been used before so it doesn't need additional time and cost to build a new one.

Sub function 2: Motor Actuator[1]

Motor actuator is the driving force needed to operate the sluice gate. Actuator have two types, the two wire system and the hard wire system. The two wire system used two main cable to operate the whole actuator and sensor that have a direct connection with the regulator source. While the hard wire system uses more than two cable to operate the actuator and the sensor. The transmission system used on the actuator is adjusted based on the design that is made, so the open close process of the sluice gate will run well.

Sub function 3: Level control[3]

Level control is the equipment needed to measure the water surface level and deliver signal to the actuator for opening and

closing of the sluice gate. Several models to input motion needed for this design are ultrasonic sensor, displacer sensor, and level switch sensor. The ultrasonic sensor emits signal that reflects on the water which will be received and read by the sensor once again and if the height of the water surface is 'abnormal', then the system (PLC) will give command to the motor actuator to lift the sluice gate. This type of sensor uses ultrasonic wave which is why it doesn't need direct contact with water. On the other hand, the sensor displacer needs to be in direct contact with the measured object (in this case is water). The performance of the sensor will eventually drop over time because the dirt and substances contained in the water causes rust and crust to form on the measuring equipment. Then there is the level switch sensor which cannot monitor by percentage of open and close position. It can only monitor when water is on the maximum position.

Sub function 4 : System Controller[5]

System controller is the main equipment to give output signal so system work according to the existing command. There are three types of system controller: Programmable Logic Controller (PLC), single loop control system, and mechanical system. Programmable Logic Control (PLC) is an electronic system which is mainly used in industrial area because of its memory which can be programmed to save instructions and implement specific functions such as logic order, timing, enumeration, and arithmetic operation to control machination or to operate procedures through digital and analog input/output operation modules. This controller system's strength lies in the capability to control and give multiple commands in a single process, the generally small size, and more than one input and output. Its weakness is that it is not easy to make instruction in programming language that supports PLC, and its sensitivity to temperature and environment change. Single loop control system is mainly used as the standard for industry automation process because of its implementation that is relatively easy with affordable maintenance cost. Its weakness is that this system is incapable to maintain the desired criteria when change toward parameter and process system happens. This system also needs regular calibration. Mechanical system has more simplistic arrangement compared to PLC and single loop control system. Its weaknesses are the disruption toward the water flow because the delay in the command to open the sluice gate and the need to have more than one person so the sluice gate can be lifted.

The variation of the conceptual design which is chosen is 1-A, 2-A, 3-A, and 4-A. The reasons behind this design are as follows:

(1A) Vertical Sluice Gate

Is chosen because it is the type of sluice gate that is generally used. In the process of upgrading an existing sluice gate performance, making new sluice gate requires a long time and high cost. Because of that it would be effective to not make any changes to the sluice gate itself.

(2A) 3-Phase Wired System[1]

The use of high-power actuators makes the selection of a 3 phase actuator very suitable for use because it is more economical (smaller electricity usage), the use of power cables that are smaller in diameter. The use of two wired systems is very good along with the times so that the control of several actuators can be controlled with only two cables. This also makes the circuit safer, easier to maintain, use fewer cables, and easier for additions and construction of other sluices.

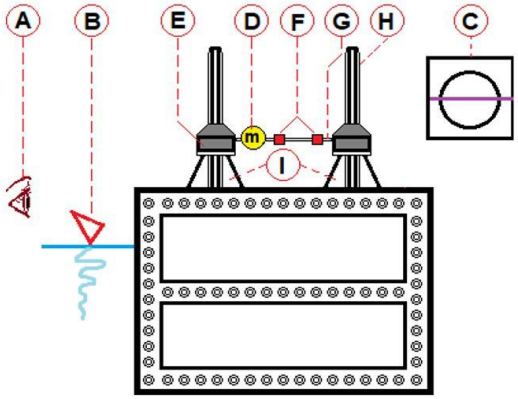
(3A) Ultrasonic Sensor[3]

By using ultrasonic sensors, the sensors used will not come into direct contact with the media to be measured, in this case is water. It lessened the possibility of rust and crust that will drop the sensor's performance.

(4A) System Controller[5]

The system control used in this design is using Programmable Logic Control (PLC). This is because the design uses drive motor, sensor, and HMI that must be monitored, so the use of PLC will be more appropriate. Also, if to consider further development in operations, PLC is perfect for this choice because of its ability to carry out multiple instructions.

Embodiment design and detail



Explanation:

(A) Level Sensor[3]

Level sensor uses the ultrasonic system to control the water surface level.

(B) Water Surface Level

Water surface level is being monitored using the 4-20mA transmitter from the level sensor to the PLC

(C) Programmable Logic Controller[5]

The 4-20mA signal result is being used to set the parameter in the PLC (controller), when in a closed condition (0%) use 4mA signal and in an open condition (100%) use 20mA signal

(D) Motor Actuator[1]

The PLC hardware have the ability to set, adjust, and give a contact signal output to move the sluice gate motor

(E) Bevel Gearbox[2]

Contact signal that is received from the actuator to connect motor with transmission gear with two clutch

(F) Coupling Shaft

From the result of the transmission being connected to the bevel gearbox to lift up the torque or sluice gate using drive bushing and thrust bearing

(G) Connecting Shaft

Is the shaft that connects the two gearboxes and the motor actuator.

(H) Spindle Shaft Sluice Gate

Is the shaft that lets the sluice gate to move upward and downward, letting the water flow through or stopping the flow completely.

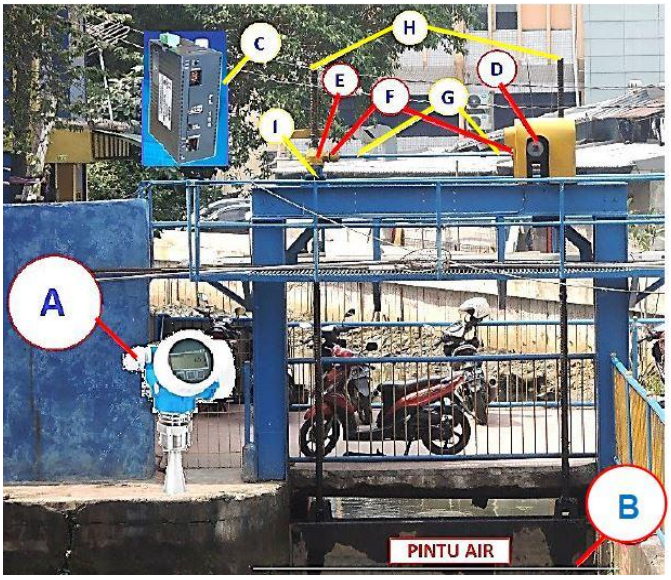
(I) Supporting Base Plate Gearbox

Is the plate under the gearbox that strengthened the gearbox to the gearbox stand on the sluice gate housing.

Prototype design and detail

Prototype Design

In this prototype assembly there are 5 (five) components that must be assembled. The first is a supporting base plate on the left and right, the second is a bevel gearbox on the left and right, the third is the installation of a motor actuator unit on the gearbox, the fourth is the installation of coupling shafts, the fifth is connecting shaft, the sixth is installation of sensor level, and the seventh is the installation of Programmable Logic Controller (PLC).



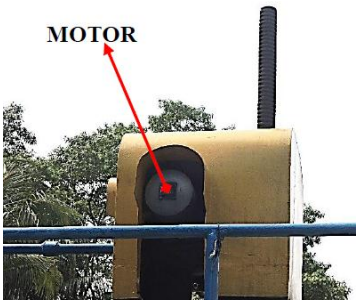
Detail

( ) Vertical Sluice Gate

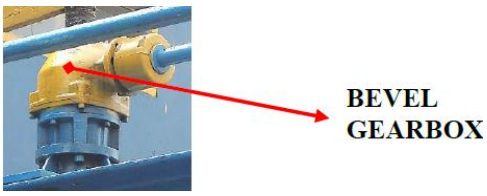
(A) Level Sensor[3]

(C) Programmable Logic Controller[5]

(D) Motor Actuator[1]



(E) Bevel Gearbox[2]



(F) Coupling Shaft

(G) Connecting Shaft

(H) Spindle Shaft Sluice Gate

(I) Supporting Base Plate Gearbox

CONCLUSION

1. The Jayakarta sluice gate has been successfully designed for automatic and manual operations.
2. From the results of research and design it can be concluded that:
    a. Operation with a system can automatically adjust the flow rate and altitude of the water level stably.
    b. Automatic opening and closing sluice gate system can take only a short time (6.4 minutes) compared to a manual system (takes 90 minutes).
    c. Only one person is needed to control the operation results monitored by HMI and to maintain the equipment.

REFERENCE

[1]https://www.auma.com/en/documents/?no_cache=1&folder=3_0_0 accessed on June 23rd, 2019

[2]Technical Data from AUMA Catalog for Gearbox 10.2 – GK 40.2

[3] https://www.endress.com/en/field-instruments-overview/level-measurement/Radar-Micropilot-FMR51 accessed on June 23rd, 2019

[4]https://www.renuelectronics.com/pdfs/FP3%20with%20IO.pdf accessed on June 23rd, 2019

[5]https://renuelectronics.com/pdfs/letter/FL100.pdf accessed on June 23rd, 2019