

# Design and Implementation of Wet Sludge Receiving, Storage and Feeding Control System Based on PLC

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**Abstract.** The wet sludge receiving, storage and feeding subsystem is the core of the sludge treatment plant project, and is apt to lead to the odor generation and the dust leakage, which will do damage to the environment. Based on the SIEMENS S7-400 homogenizing treatment of the sludge through the control system and the usage of the hydraulic double-shaft spiral system, the whole system shall be sealed and free from leakage, resulting in an excellent commissioning effect.

## Introduction

The total sludge processing capacity of a sludge treatment plant project is 45t/d and the processing capacity of the first phase of the project is 300t/d, so the sludge receiving and transport system will be designed per the capacity of 450t/d. The sludge is treated with the drying process, namely the drying treatment will be applied to the dewatered sludge in the municipal sewage treatment plant with the paddle drying machine at the sludge drying capacity of 3 \* 100 t/d production lines. The objective is to dry the sludge with the water content from about 80% to 10~30%. The wet sludge receiving, storage and feeding system is the core of the sludge treatment plant to realize the receiving, storage and transportation of the sludge. The homogeneity of the sludge shall be realized through the control system in order to ensure that the sludge entering into the subsequent is homogenous. The model and material of the equipment shall be determined according to the sludge characteristics in order to make the system with good corrosion and abrasive resistance. The receiving process is closed and free from the odor and dust leakage.

## Overview of System and its Flow Chart

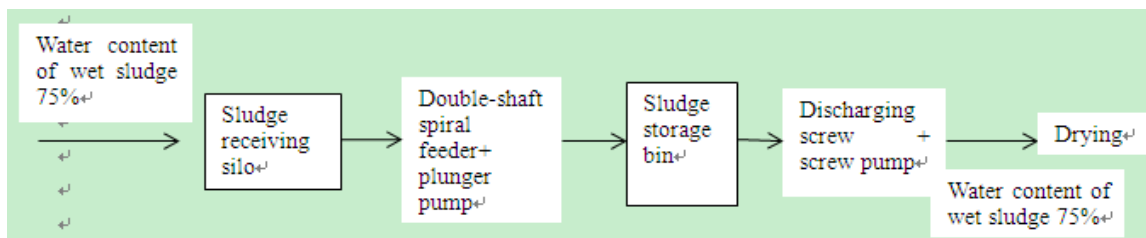


Fig .1 Flow Chart of the System

After being transported to the system by truck, the sludge is firstly discharged into the sludge receiving steel silos and there is no pollution in the entire process. The sludge receiving silos are rectangular underground stock bins with the effective volume of 100 m<sup>3</sup> each. After the sludge is discharged into the receiving silos, the hydraulic arch breaking carriage will carry out the reciprocating motion at the bottom of the bin to prevent the sludge from bridging in the unloading

area and continuously transport the sludge to the hydraulic double-shaft spiral conveyor at the bottom of the silo. The receiving silo is equipped with the online ultrasonic level gauge to monitor the silo. After receiving the sludge from the arch breaking carriage, the hydraulic double-shaft spiral conveyor will feed the hydraulic plunger pump in the pressurization way. After the storage bin receives the pumped sludge, the hydraulic arch breaking carriage at the bottom of the bin will carry out the reciprocating motion to prevent the sludge from bridging in the unloading area and continuously transport the sludge to the electric single-shaft discharging screw at the bottom of the silo. And then the sludge will be transported to the feeding screw pump of the drying machine. Each drying machine can receive the sludge from two wet sludge storage bins so that the screw pump or the bin can be standby.<sup>[1][2]</sup>.

## **Overall Plan of Automatic Control System**

The sludge treatment process control is a process control and the S7-400 fully-integrated automatic controller from the Siemens is used as the main controller according to the technological requirements. The automatic control system adopts the DCS system architecture which mainly includes four layers: the field instrument layer, control unit layer, factory (workshop) layer and enterprise management layer. This project provides three layers except the enterprise management layer, and the enterprise management layer will be connected to the management software platform of the Third Party via the open data interface. The Industrial Ethernet (Industrial Ethernet) and PROFIBUS-DP field bus will be used for the communication network.

The workshop control room is located in the sludge treatment plant and implements the centralized monitoring, control and management of the production process and the technological process of the whole sludge treatment plant. There are five on-site control units (PS01 ~ PS05) to directly control and monitor the production processes, conduct the signal acquisition, monitoring and control of the process detecting parameters and equipment operation conditions, and transmit these signals to the superior control unit in a real time. The SIEMENS PCS7 system is used in the project.

## **System Function**

**Sludge Receiving System.** The wet sludge receiving system consists of the wet sludge receiving silo (including carriage and cover), screw feeder, sludge delivery pump and hydraulic station. All power devices of the wet sludge receiving system are driven by the hydraulic power unit. The hydraulic power unit in the receiving silo and other auxiliary facilities are equipped with the control cabinets which are controlled by 1 # field control station.

The work process of the receiving system is: When the sludge transport cart arrives at the sludge silo, the sludge hydraulic cover is opened so that the transport cart can discharge the sludge into the sludge receiving silo. After the transport cart leaves, the hydraulic sliding cover is quickly closed; then the hydraulic station and the carriage are started successively. Later, the corresponding oil cylinders will be started to work in sequence. The oil cylinders are interlocked and only one cylinder works each time. In general, the starting/stopping of the oil cylinder is controlled separately. While the screw feeder and the plunger pump are controlled at the same time but are started successively. The hydraulic station should be started before the system operation. The control cabinet has automatic and manual control modes and can monitor the operation, starting/stopping, accident alarm, material level and other conditions of the cover, the carriage, the screw feeder and the plunger pump. At the same time, the control cabinet will send the signal to the workshop control room and is controlled by the workshop control room.

The control descriptions of the components of the wet sludge receiving system are as follows:

(1) Silo cover. The hydraulic sliding cover of the receiving silo is controlled by manual on the scene, and the cover location will be monitored by the control system. When the sludge transport cart arrives at the sludge silo, the sludge hydraulic cover is opened so that the transport cart can discharge the sludge into the sludge receiving silo. After the transport cart leaves, the hydraulic sliding cover is quickly closed. The sludge receiving silo is equipped with two sets of ultrasonic level gauges which can allow the information of the material level to be displayed on the DCS to give a prompt for the location of the receiving silo available, facilitating the dispatching of the sludge silo material level.

(2) Carriage. The carriage has three control modes, namely manual, automatic and DCS control modes. The manual mode is designed for the maintenance, and in this mode, the pulling/ pushing operation of the carriage can be realized by pressing the buttons on the field control cabinet. The auto mode will be controlled by the program. In the DCS mode, the operation will be done in the workshop control room. The starting order is the same, and the carriage can move forward and backward through the program control. The approach switch can detect it when the carriage moves to the desired position. Besides, the arch breaking carriage is equipped with the pressure limit unit, and is driven by the hydraulic cylinder to move back and forth so as to push the sludge into the discharging screw unit.

(3) Double-shaft spiral feeder. The spiral feeder includes three control modes, namely manual, automatic and DCS control modes. The manual mode is designed for the maintenance, and in this mode, the starting/stopping can be realized by pressing the buttons on the field control cabinet. The auto mode will be controlled by the program. In the DCS mode, the operation will be done in the workshop control room. Several electric gate valves are installed on the outlet of the double-shaft spiral feeder to realize the maintenance and management of the pump and pipeline. The starting/stopping and alarm signals of the feeder are sent to DCS and the starting/stopping of the feeder is interlocked with the plunger pump.

(4) Hydraulic plunger pump: The plunger pump adopts the double-cylinder and S-shaped swing pipe structure. The sludge pump also includes manual, automatic and DCS control modes. The manual mode is designed for the maintenance, and the actions of the main and secondary oil cylinders for the pump can be realized by pressing the buttons on the field control cabinet in this mode. The auto mode will be controlled by the program. In the DCS mode, the operation will be done in the workshop control room. The piston cylinder is controlled by the gradual switch and the pressure control. The transfer operation of the pump is controlled by the gradual switch with the transfer time adjusted. The displacement of the pump can be set on the touch screen of the DCS system at 4 ~ 20 mA. The electric valve is located at the outlet of the plunger pump for the maintenance of the plunger pump and the pipeline management. <sup>[3]</sup>

(5) Hydraulic station: The hydraulic station is equipped with the lubrication system as the attachment for the lubrication of the necessary lubrication points. The hydraulic station is equipped with the power overload protection circuit and the control cabinet. Among them, the control cabinet is linked with the DCS looped network via the DCS field workstation under the control of the workshop DCS system. The control cabinet has automatic and control modes to realize the control and monitoring of the whole system, including monitoring the operation, starting/stopping, accident alarm, material level and other conditions of the cover, the carriage, the screw feeder and the plunger pump as well as sending the signal to the workshop control room after the logical operation as programmed.

**Wet Sludge Storage and Transportation System.** The wet sludge storage and transportation

system consists of the wet sludge storage bin, carriage, discharging screw, sludge delivery pump and hydraulic station. Among them, the carriage is driven by the hydraulic unit, while the discharging screw and the sludge delivery pump are driven by the motors. The hydraulic system is equipped with a control cabinet. The control cabinet, the discharging screw and the sludge delivery pump communicate with 1 # field control station and are controlled by the workshop level control system at the same time. <sup>[4]</sup>

The work process of the wet sludge storage and transportation system is: Firstly, check the material level signal of the storage bin and turn on the corresponding electric ball valves according to the signal and the starting signal of the plunger pump so as to let the sludge enter. Then, control three bins for the even feeding according the material level monitored by the material level gauge. The hydraulic station and the carriage are started. And then control the corresponding oil cylinders in sequence. The oil cylinders are interlocked and only one cylinder works each time. The control cabinet includes automatic and manual modes and can monitor the operation, starting/stopping, accident alarm, material level and other conditions of the carriage, and simultaneously transmit the signal to 1 # field control station and be controlled by the station. In general, the starting/stopping of the carriage will be controlled separately. For the starting/stopping of the discharging screw, the logical operation will be conducted according to the material level as well as the conditions of the drying machine and flow meter so as to determine the screw to be opened and its rotation direction and then start the corresponding screw. Later, start the corresponding electric screw pump according to the screw signal. The discharging screw and the screw pump are controlled at the same time. The linkage control will be applied to the sludge pump, the sludge receiving silo, the material level of the sludge storage bin and the sludge conveyor. Provided that the sludge conveyor runs normally, when the sludge receiving silo meets the discharging conditions and the sludge storage bin meets the receiving conditions, the sludge pump will be in normal operation; if any signal fails to meet the requirements, the sludge pump will automatically stop working. The pump control box will send the signals to the remote I/O module, and then be connected with its control station by bus. The running status and working conditions of the pump are sent to the workshop control room. Then the workshop control room can control the operation of the pump and set the controlled water level of the pump. The continuous and automatic monitoring, display and recording functions of the whole system will be realized through the control of the wet sludge receiving and conveying system as well as the signal acquisition of the bin level, methane content, sludge quantity gauges and other instruments in order to guarantee the normal operation of the processes and equipment used.

## **Conclusion**

The field control station of the wet sludge receiving and storage and transportation system is responsible for the control of the system and is mainly used for the acquisition of the process parameters and the network connection. The control station consists of the CPU module, power supply module, DI, DO, AI and AO modules, and a variety of network communication interface adapters, power supply and signal lightning protection devices and a variety of isolators. The control modes include the on-site control, remote manual and automatic operation mode. The condition parameter lists of all the equipment can be uploaded to the central data system, and then be displayed in the workshop control room in a centralized way or be authorized for the necessary intervention to the equipment on the scene. The continuous and automatic monitoring, display and recording functions of the whole system will be realized through the control of the wet sludge receiving, storage and transportation system as well as the signal acquisition of the bin level, methane content, sludge quantity gauges and other instruments in order to guarantee the normal

operation of the processes and equipment used.

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