Aluminium Smelter Multifunctional Overhead Crane - Intelligent Servo Control of Hydraulic System

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Abstract

The aluminium smelting industry is currently accelerating its transition toward high-end and intelligent development, with core equipment like multifunctional overhead cranes being in urgent need of technological upgrading. The traditional aluminium tapping operations suffer from low efficiency and high error rates, with such issues as excessive oil temperature, high energy consumption and inadequate motor protection in their hydraulic system. The intelligent servo control hydraulic system is a critical breakthrough. An intelligent servo control hydraulic system integrates servo drives, programmable logic controllers (PLC) and sensors has been developed in order to address the problems in the existing multifunctional overhead crane hydraulic systems, such as excessive oil temperature, high energy consumption and inadequate motor protection. This system effectively eliminates redundant flow and energy loss through precise regulation of flow and pressure, achieving significant energy savings while simplifying system architecture and upgrading protective functions. This paper provides a reference for the intelligent upgrading of the existing multifunctional overhead cranes used in the aluminium smelting industry.

Keywords: Aluminium electrolysis, Multifunctional overhead crane, Intelligent servo control, Hydraulic unit drive.

1. Research Background and Technical Challenges

1.1 Industry Status and Demand for Intelligent Transformation

The aluminium smelting industry is an energy-intensive and capital-intensive industry. Its aluminium production efficiency and intelligent production directly impact national resource strategies and industrial competitiveness. In recent years, with the advent of the Chinese "dual carbon" goals and the advancement of Industry 4.0, the aluminium smelting industry has been undergoing profound transition toward high-end, low carbon and intelligent production. The multifunctional overhead cranes (also known as pot tending machines, or PTMs) perform various critical, high-frequency, and high-intensity tasks, including breaking bath crust, tapping aluminium, changing anodes, raising anode beam busbars, etc. Their performance and intelligence directly dictate the efficiency, energy consumption, safety, and stability of the entire potline. However, the core systems of the traditional multifunctional overhead cranes that are widely used at present, particularly the hydraulic drive system, cannot meet new requirements of intelligent production technically, becoming a major bottleneck that hinders industrial upgrading.

1.2 Analysis of Existing Issues in Hydraulic Drive Systems

The hydraulic system is installed on the overhead crane's rotating mechanism, which operates in a harsh environment above the pot, where the temperature frequently exceeds 50 °C. In addition, under the proportional control mode, the oil pump maintains constant operation at a rated speed with a steady 20 MPa outlet pressure, while the actuator requires 8–12 MPa only. The constant-speed operation of the fixed displacement pump generates 40 % excess flow. When the surplus pressure flow passes through the throttle valve and relief valve, throttling loss and overflow loss will occur, both of which will cause the system to heat up, resulting in high oil temperature. Even with air heat exchangers, cooling effectiveness remains limited, particularly during the summer when hydraulic oil temperature reaches 60–80 °C. Prolonged high oil temperature severely impacts the service life of the hydraulic fluids, hydraulic components and seals, accelerating seal aging. Additionally, prolonged operation of the air heat exchanger at high oil temperature can easily lead to overheating and burn out the motor of the cooling fan.

The hydraulic system is installed on the overhead crane's rotary mechanism and so the three-phase power supply must be routed through rotary cables to reach the motor control cabinet and as a result circuit phase loss frequently occurs during operation. However, the reliance on thermal relays for the motor phase loss protection leads to motor burnout due to the inability of the thermal relays to offer effective protection in the event of a phase loss. The reason for that is that thermal relays have two major limitations:

1. Detection hysteresis: In the event of a phase loss, enough heat needs to be accumulated to trigger protection, with a response delay of up to 2–3 seconds, making it impossible to achieve millisecond rapid cut-off, and thus resulting in winding overheating and burnout;
2. Inadequate sensitivity: The strong magnetic fields and load fluctuations in the potline can easily cause malfunction.

2. Urgency of Integrated Intelligent Upgrading

An intelligent servo control hydraulic system is proposed to address the problems in the existing hydraulic system as shown in Figure 1.

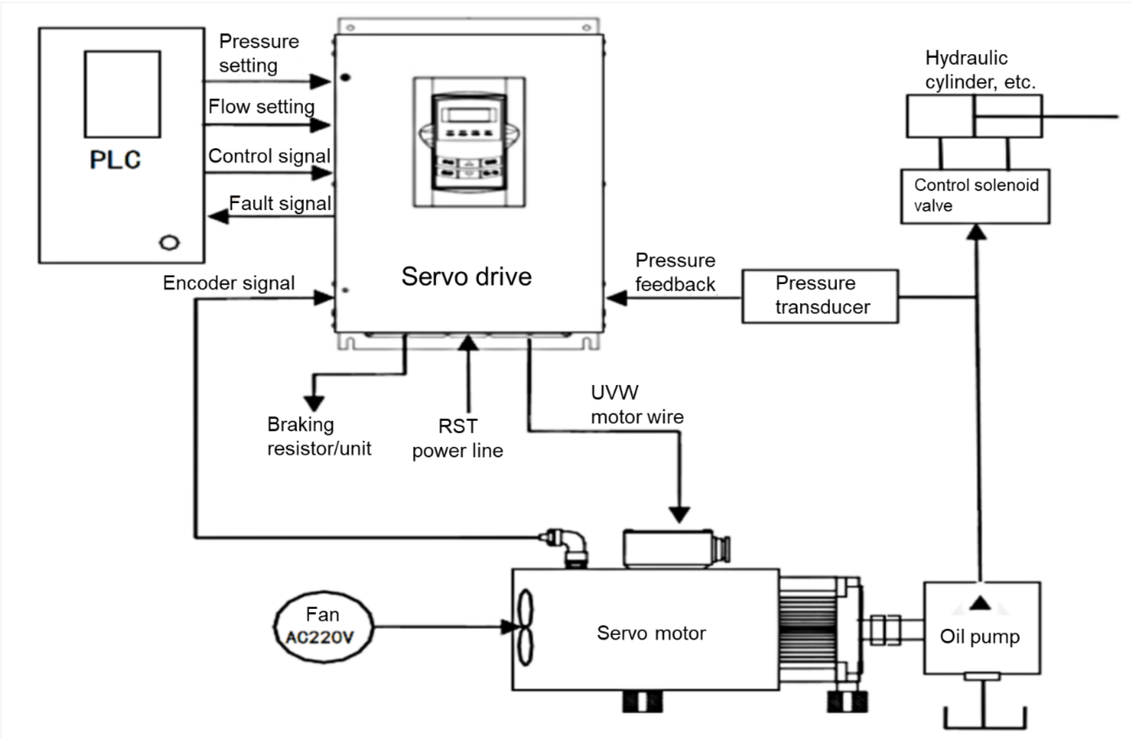

Figure 1. Diagram of intelligent servo control hydraulic system.

The system consists mainly of a PLC, an oil pump, a servo motor, a servo drive, a pressure sensor, a rotational speed sensor, a hydraulic directional valve and accessories. The high-precision pressure sensor is installed at the outlet of the oil pump and the servo drive is housed in the electrical control cabinet. The pressure and flow demand values for each circuit are sent by the