IMPROVEMENT OF TEMPERATURE CONTROL PROCESS IN INDUCTION FURNACES FOR STEEL MELTING

Olimov Abduvohid Shuxrat ugli
Andijan State Technical Institute
4th year student, Automation and Control of Technological Processes and Production (by branches) direction
E-mail: Olimovabduvohid580@gmail.com | Tel: +998 88 054 11 74
Scientific supervisor: Sultonov Ildar

Abstract: This thesis examines the improvement of the temperature control process in induction furnaces used for steel melting. The shortcomings of existing conventional thyristor-based control systems are analyzed, and methods for improving temperature control based on a PID controller and IGBT technology are recommended. Research has shown that a PID system tuned using the Cohen-Coon method maintains the melting temperature within ±12°C accuracy, reduces energy consumption by 18.6%, and significantly improves casting quality.

Keywords: induction furnace, steel melting, PID controller, IGBT, temperature control, improvement, Siemens S7-300.

Introduction - Induction melting technology is based on heating the metal charge directly through electromagnetic induction, and compared to conventional arc furnaces, it stands out for its high energy efficiency (85–92%), clean melting environment, and precise temperature control capability. The melting temperature for various steel grades ranges from 1480 to 1650°C, and deviations exceeding ±50°C from the set value deteriorate the chemical composition, mechanical properties, and microstructure of the casting [1].

Many enterprises still use simple thyristor control or manual adjustment systems. In such systems, temperature fluctuates within ±50–80°C — an unacceptable figure from the perspective of high quality standards and energy

efficiency. Therefore, improving induction furnace temperature control based on modern PLCs and PID controllers is a pressing issue [2].

Main Body - *Shortcomings of the existing system.* In conventional thyristor control, the power supplied to the heating element is regulated only by changing the firing angle. The main drawbacks of this method are: low power factor cos φ (0.6–0.7), large harmonic generation in the power grid, significant temperature fluctuations (±50–80°C), and high energy waste. Moreover, manual adjustment depends on the operator's skill level, causing results to vary from cycle to cycle.

Improvement directions. Three main directions are recommended to improve the system:

— Replacing the power control element from a thyristor to an IGBT-based frequency converter (Siemens SINAMICS G150, 400 kW). IGBT technology ensures cos φ > 0.95, reduces harmonics, and increases energy efficiency by 12–15%;

— Replacing the temperature sensor from a Type K thermocouple to a Type S (platinum-rhodium) thermocouple and providing EMC protection via a Siemens SITRANS TR300 transmitter. The Type S thermocouple operates with ±1°C accuracy up to 1600°C;

— Implementing a PID controller based on Siemens S7-300 PLC (FB 41 PID block) with parameters calculated using the Cohen-Coon method.

PID parameters and comparison. The transfer function of the induction furnace is expressed as $W(s) = 0.0436 \cdot e^{-45s}/(2403s+1)$, and the optimal parameters calculated using the Cohen-Coon method are: Kp = 7.42; Ki = 0.061; Kd = 28.40.

Table. Comparison of control methods

Indicator	Conventional	Z-N PID	C-C PID
Temperature error (°C)	±62	±18	±12
Overshoot (%)	9.8	6.4	2.7

Energy consumption (kWh)	348	298	283
Energy savings (%)	—	14.4	18.6

As seen from the table, the Cohen-Coon PID system improves temperature accuracy 5.2 times compared to conventional control (from ±62°C to ±12°C), reduces overshoot 3.6 times, and saves 65 kWh of energy (18.6%) per melting cycle.

System composition. The improved system consists of the following devices: Type S thermocouple (×2, primary and backup) + SITRANS TR300 transmitter; Siemens S7-300 PLC (Cohen-Coon parameterized PID); SINAMICS G150 IGBT frequency converter (400 kW); Siemens MP 277 HMI operator panel (10"); WinCC SCADA system (archiving and reporting). During 10 melting cycles tested on the real system, the steady-state error was ±14°C and energy savings reached 17.2%.

Conclusion - The following results were obtained on improving the temperature control process in induction furnaces for steel melting:

1. The main shortcomings of conventional thyristor control (±62°C temperature fluctuation, low cos φ, high energy waste) were identified and methods to eliminate them were demonstrated.

2. A PID system tuned using the Cohen-Coon method (Kp=7.42; Ki=0.061; Kd=28.40) controls melting temperature with ±12°C accuracy — 5.2 times better than the conventional system.

3. Switching to IGBT technology enables savings of 65 kWh (18.6%) of energy per melting cycle.

4. The proposed integrated system (S7-300 PLC + SINAMICS G150 + WinCC SCADA) was tested in real production and confirmed the expected results.

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