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Research on Intelligent Control System of Fused Magnesium Furnace Based on Embedded System

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In order to deal with the unstable control process and the high energy consumption of the fused magnesia furnace, the overall framework of the embedded control software for the fused magnesia furnace was designed. Firstly, the function of embedded control platform software for fused magnesia furnace is designed. Then, the embedded control platform software of the electric melting magnesium furnace is developed, including the self-test function module, the work condition recognition function module and the work condition processing function module. Each module is described in detail. The internal interface is designed. Finally, the embedded control software is simulated under the condition of abnormal three-phase ultra-high limit. The results show that the control software is reliable and effective. It can not only achieve the established control objectives, but also reduce the power consumption to a certain extent, thereby reducing the impact of excessive current on the grid.

1. Introduction

Fused magnesia is widely used in aerospace, metallurgy and other industries as a good refractory material with high melting point, dense structure, strong oxidation resistance, strong corrosion resistance and stable chemical properties (Fang et al., 2013). With the expansion of the application range of fused magnesia, more and more countries and enterprises begin to pay attention to the production, research and application of fused magnesia, as figer 1 shows. The energy consumption of fused magnesia is enormous, and the power consumption per ton of fused magnesia is about 2600-3000 degrees per ton. Electricity costs account for more than 60% of the total production cost (Ahmad, 2016), and magnesium oxide crystals are also very different in terms of their purity range and price (Leena, 2013). Therefore, reducing the power consumption of the product and improving the grade of the product are the two goals of the smelting of fused magnesia. Because the process is complicated, and the disturbance is frequent, it is difficult to establish an accurate mathematical model (Jie and Tianyou, 2016). In order to achieve the two goals, higher requirements are put forward for the design of the control program of the fused magnesia furnace. The application of embedded controller in the field of industrial control provides a good solution to this problem (Yang et al., 2014). At present, the advanced embedded controller has high hardware configuration and perfect software platform support. Most of the system software is embedded operating system with hard real-time characteristics, which can meet the strict requirements of real-time industrial control (You et al., 2017). However, the development of software is often a powerful integrated development environment. Both the control program development and the monitoring software development fully consider the convenience and efficiency of human computer interaction.

To deal with the unstable control process and the high energy consumption of the fused magnesia furnace, this paper designed the function of embedded control platform software for fused magnesia furnace and developed the embedded control platform software of the electric melting magnesium furnace, including the self-test function module, the work condition recognition function module and the work condition processing function module. The embedded control software is simulated under the condition of abnormal three-phase ultra-high limit.

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Figure 1: Intelligent control of electric melting furnace

2. General framework of embedded control software for fused magnesia furnace

2.1 Overall architecture design of embedded control software for fused magnesia furnace

In this paper, we use the MATLAB / Simulink / Stateflow platform (John et al., 2012) to study and develop the overall architecture of embedded magnesium furnace embedded control software. The embedded control platform software is the basis of the control algorithm software and the running platform, and the control algorithm software will realize the control algorithm. The software system directly faces the user, and all functions of the system are realized by software, such as system management, scheduling, and control functions. The software can easily change or expand the function of the system, and has good flexibility (Mehdi et al., 2014). The architecture of software system must be reasonable, it has a clear hierarchy, which not only meets the requirements of openness, but also easy to maintain.

2.2 Software design of embedded control platform for fused magnesia furnace

According to the melting process of the fused magnesia furnace, the embedded control platform software of the fused magnesia furnace should have the following functions: The software of magnesium melting furnace control platform must be able to realize the data acquisition of three-phase current and voltage. In this way, the control algorithm software can process the current and voltage data at all times and then generate the drive signal (Per et al., 2016). Electric melting furnace control platform software must have self-test function to ensure the normal production and troubleshooting in production. The fused magnesium furnace control software must have the condition recognition and processing function and the motor execution function. The fused magnesium furnace control software must be able to support graphical programming and can generate independently executable C code for embedded control systems for real-time control. The control software of the fused magnesia furnace must be able to communicate between the host computer and the target machine. The real-time data interaction must be performed between the host and the target machine.

3. Development of embedded control platform software for fused magnesia furnace

3.1 Development of self-checking function module

The self-test function is the necessary operation to control the system when it is powered on. The hardware platform of the control system can be checked by self-checking function, which is the precondition for the smooth production of the dissolved magnesia. At the same time, it also provides convenience for the later fault investigation. For the melting process of the fused magnesia furnace, the output is directly connected to the input terminal. Then it can be reused with manual input and combined with control software to realize self-test function (self-checking depends on the setting of the control program to its control end) (Gabriella et al., 2016). If the self-test module fails, it needs to alarm to detect the platform fault, so its output should be connected to the interface of the alarm lamp. The specific interface is shown in Figure 2.

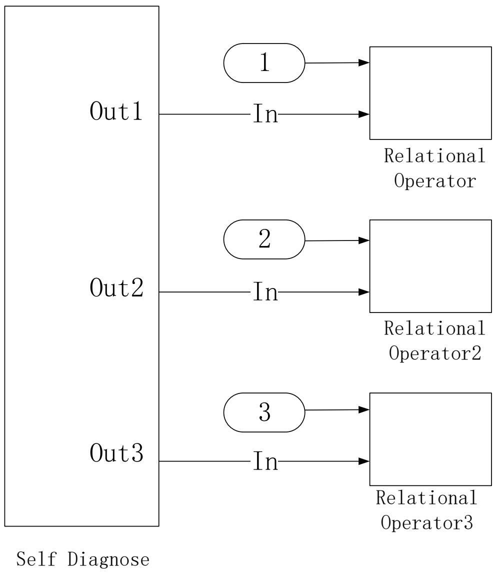

Figure 2: Design of self - test function module interface

3.2 Development of function module for work condition recognition

The working condition recognition module is used to identify the current smelting process (Víctor et al., 2017). It can be seen from the figure that in the working condition identification part, there are seven input variables, namely three-phase current and four real-time collected variables (Luminada et al., 2014). At the same time, the current set value is introduced as an input, which facilitates the real-time setting of the current setpoint. In order to distinguish the charging and exhaust conditions, the feed and exhaust button action signs are introduced, which are used to distinguish the current feed and exhaust conditions. The output is the identification of the current operating conditions, the parameters of the current operating conditions, and the range of current fluctuation (Zhi-Wei et al., 2014). This is convenient to handle the real-time processing of the current working conditions, so as to achieve stable control of three-phase current, thereby improving the production of high-purity products. The internal interface of the function module is shown in Figure 3.

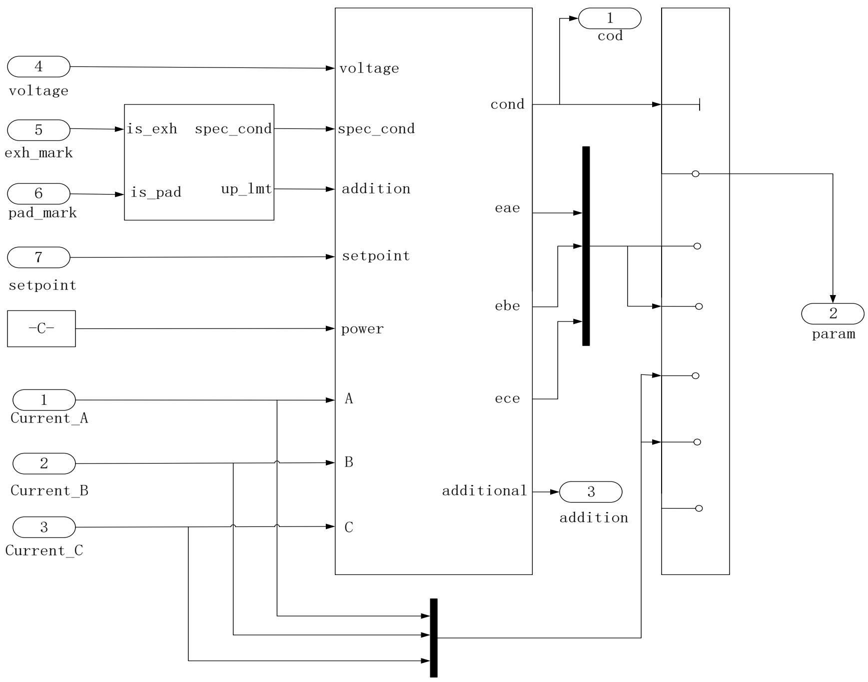

Figure 3: The internal interface of the function module

In the above input / output interface and the internal detail interface description, it is mentioned that some parameters of the current operating condition need to be transferred to the next function module for processing. The actual significance of the parameters and parameters passed by the working condition recognition module under various working conditions is shown in Table 1.

Table 1: Passing parameters table of condition analysis

Cond	Cond meaning	The parameters and meaning
1	Three extremely exceed	None
2	Two extremely exceed	Overrun flag (eae,ebe,ece)
3	One extremely exceed	Overrun flag (eae,ebe,ece)
4	Normal	Current value (CurrentA/B/C) and fluctuation range(addition)
5	Exhaust	Current value (CurrentA/B/C)
6	Power exceed	None

3.3 Development of working module for working condition

The condition processing is handled according to the operating conditions and parameters identified by the function module (Chen et al., 2014). It can transmit different parameters to the output drive function module, and provide drive signal for the lifting of the three-phase motor. The corresponding electrodes are driven to perform corresponding lifting operations to achieve control objectives (Fedin et al., 2016). Its interface as shown in Figure 3: the leftmost inputs are the cond (working condition), the param (parameter), and the addition (fluctuation range) delivered by the previous function module. The lower part is the internal interface diagram of the work condition processing function module. Among them, the first three frames represent three phase abnormal overrun, two phase abnormal overrun and single-phase abnormal overrun conditions. The fourth frames in the middle represent the normal working condition. The next frame represents the exhaust condition, and the last one represents the power overrun condition. The right side output represents the action signal flag of A, B and C three-phase electrodes, and it is passed to the output drive function module. The internal interface definition of function module for condition handling is shown in Figure 3.

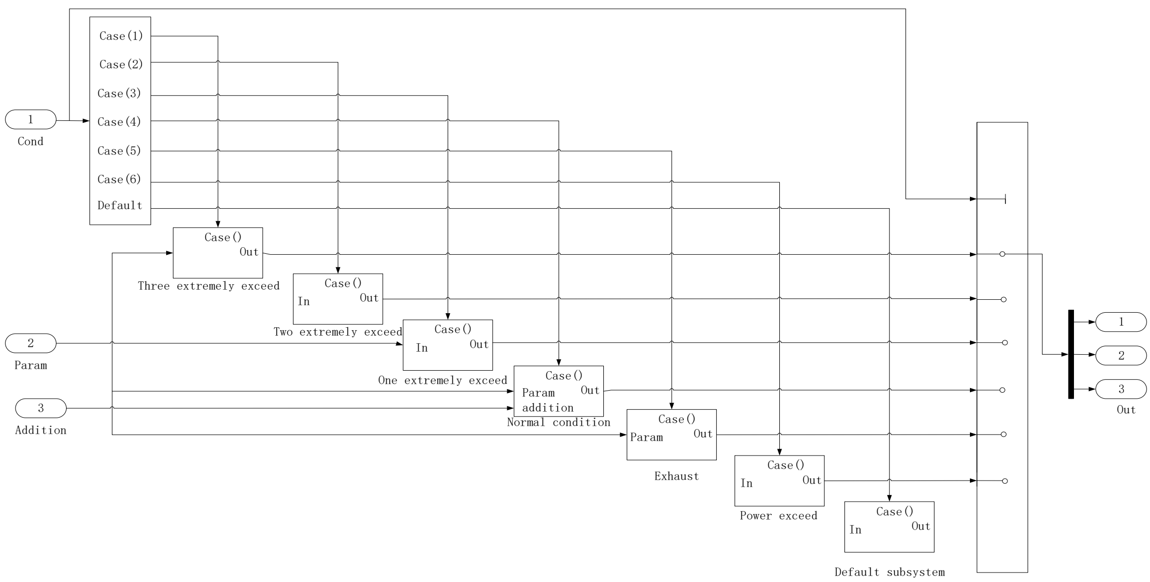

Figure 4: The internal interface definition of function module for condition handling

The actual significance of the parameters and parameters passed by the working condition module is shown in Table 2.

4. For fused magnesia furnace

Table 2: Passing parameters table of condition handling

Cond	Cond meaning	The parameters and meaning
1	Three extremely exceed	[1,1,1] three-phase motors are upgraded
2	Two extremely exceed	The situation is slightly different
3	One extremely exceed	The situation is slightly different
4	Normal	The situation is slightly different
5	Exhaust	The situation is slightly different
6	Power exceed	[1,1,1] three-phase motors are upgraded

Table 3: Real-time simulation experiments under extremely surpass condition

Cond	Input			Expected output		
extremely exceed	A current	B current	C current	A	B	C
Three extremely exceed	13600	13650	13700	1	1	1
	13600	13650	10000	1	1	0
Two extremely exceed	13600	10000	13650	1	0	1
	10000	13650	13600	1	1	0
	13600	10000	10000	1	0	0
One extremely exceed	10000	13600	10000	0	1	0
	10000	10000	13600	0	0	1

The real-time simulation experiment environment of the embedded control software for magnesium dissolving furnace mainly adopts the real-time kernel and the external model of the operating system. The simulation of the abnormal high current of three phase current in the melting process of magnesium melting furnace is carried out. This condition requires that the three-phase current value be set higher than the set abnormal high limit setting (Suping et al., 2016). Among them, the voltage is 100, feeding and exhaust are 0 (James and Marlyn, 2013). The results show that the output of the verification result in the simulation is consistent with the expected output, and the expected control target is achieved. It shows that the embedded control software of the magnesium dissolving furnace has the basic conditions in the hardware in the loop simulation platform and the industrial field verification.

5. Conclusions

Based on the requirements of the digestion process of the electrolytic magnesium furnace, the overall design of the embedded control software of the fused magnesia furnace was designed. According to the smelting process of the fused magnesium furnace, the function design of the embedded control platform software for the fused magnesia furnace was carried out. According to the overall structure of the embedded control software of the fused magnesia furnace, the embedded control platform software of the fused magnesia furnace is designed and developed. The platform has the function of integrating self-test, working condition recognition and processing. Through field verification, it is found that the platform software is an effective platform for further research on embedded control system of electric melting furnace. Under the more comprehensive conditions, the melting process of the fused magnesia furnace can be effectively controlled.

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