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Baking Arithmetic and Error Analyses for PEFP Fundamental Power Couplers

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1. Introduction

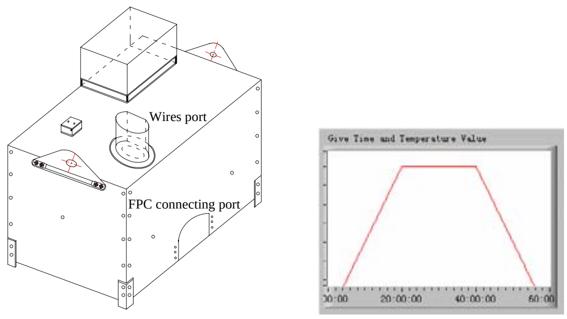
The Proton Engineering Frontier Project (PEFP) is considering developing and using SRF technology to accelerate a proton beam at 700 MHz in its present project and its extended project (PEP) [1, 2]. The first section of the PEFP SRF linac (SCL) is composed of low-beta cryomodules. Each cryomodule has three 5-cell cavities and each cavity has one fundamental power coupler (FPC). Before the high power RF processing, each FPC needs to be baked out for 24 hours at 200 degrees Celsius (ºC) [3]. The whole control system is described in reference [4], in this system, the temperature in the baking-box need to be changed according to three straight lines with different slope. This paper described how we can make the temperature of the baking-box changed according to the required values.

2. Description of the baking-box and baking process

The inner volume of the the baking-box (as seen in Fig.1 (a)) is 723mm*481mm*820.5mm, in order to insulate from the outer circumstance, it has three insulation layers which are made of: MgO and SiO2, refractory fiber cotton, the A_2O_3 and SiO_2. The three layers can protect most of the heat emitting from the baking-box. But the wires port and the FPC connecting port may leak a little heat to outer space. So, in the heating process, when deciding the number of the heater, the heat leakage should be considered.

The required temperature variation in the baking-box is shown in Fig 1 (b), the x-axis represents the baking time (hours), and the y-axis is the temperature (^{0}C). The whole baking time is 60 hours: 20 hours for increasing the temperature from the room temperature to 200^{0}C, 20 hours for holding the temperature at 200^{0}C and 20 hours for decreasing the temperature from 200^{0}C to the room temperature evenly [5].

Referring to the ordinary oven's volume and power, combining PEFP baking conditions (the ordinary oven is a close space and our baking box has two interchanging channel with outside space). We adopted 12 heater bar with one 220V, 220~330W, thus the whole power can be controlled within 0~3960W. 12 heaters are installed on the four inner walls of the baking box uniformly, each wall has three heaters. It is enough for the baking process, normally, 8 heaters are used and the other 4 are the substitutes.



(a) The baking-box (b) Required temperature line
Fig.1. The baking-box and ideal temperature

3. Algorithmic designing and implement

Two methods for the baking system have been researched, one is the PID control with some analog output modules, which has high control precise, but the hardware circuits will be complex; the other is the normal control with digital output modules, its outside circuits are simple and the control process will be easier. Through error analyses and correction, the second control method can satisfy our control requirements and has been adopted. An Allen Bradley (AB) SLC 5/05 PLC and its two 1746-OAP12 modules are used to control the heaters. The 1746-OAP12 is a numerical module and its biggest current is 2 Amp on each point. To assure the modules' safety, 12 fuses which is 1.5 Amp are fixed on each of the output electro circuit of the 1746-OPA12 separately. The 1746-OAP12 modules give 220V voltage to each heater. Because the system requires that the temperature rise or decrease evenly and hold for 20 hours on its top

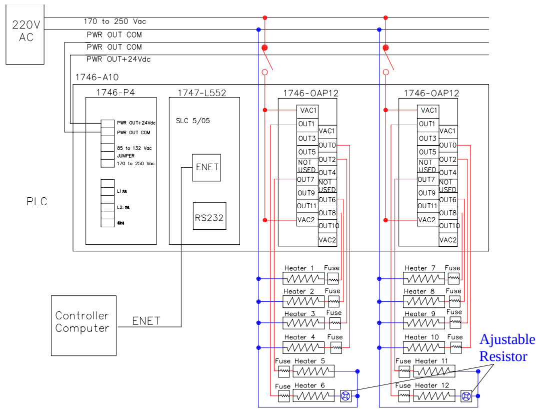
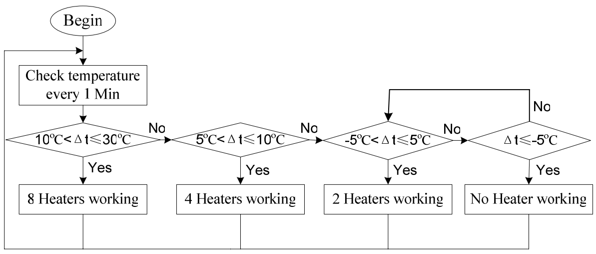


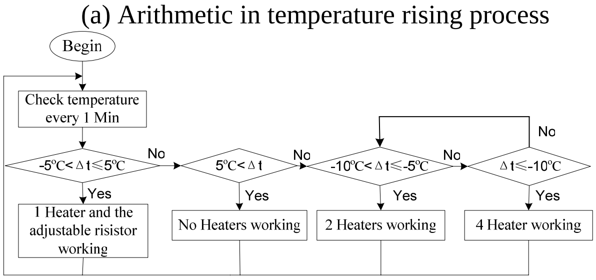
Fig.2. The circuits of PLC and its 1746-OAP module

temperature. So an adjustable resistor is installed in the sixth and eleventh heater's circuits, as seen in Fig.2. It is used to adjust the whole power evenly.

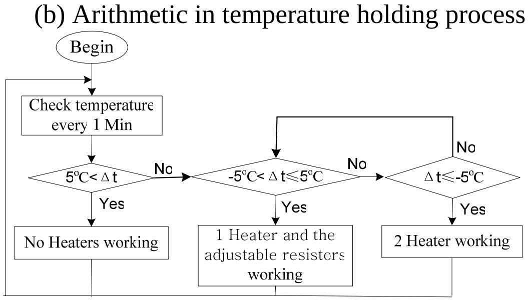
Figure 3 shows the arithmetic in the three baking process. Every one minute the PLC checks the baking-box's temperature. $\triangle t = T_i - T_r$, T_i represents the ideal and required temperature, T_r is the real temperature. In the first 24 hours baking, PLC implements Fig.3 (a) arithmetic; in the middle 24 hours' baking process, Fig.3 (b) arithmetic is adopted; the arithmetic in Fig.3 (c) is carried out in the last 24 hours of the whole baking process. The adjustable resistor is adopted when open or close one heater can not make the temperature has a slippery change. The working heaters number is depended on the $\triangle t$ value and which arithmetic adopted is decided by the PLC clock and the set values.



(a) Arithmetic in temperature rising process



(b) Arithmetic in temperature holding process



(c) Arithmetic in temperature decreasing process

Fig.3 Baking arithmetic

4. Error analysis and correction

In this system, error may come into being in three ways: 1. the inaccurate temperature reading; 2. the error in recording the temperature values; and the last one is the heater number's change will make a 330W power change in the baking-box at least. For the first error, we improve the thermocouples' reading precision and adopt the thermocouple compensator. Because the thermocouple works according to its two pole's difference in temperature, in normal, it will give its cold cathode temperature a default value, and the temperature reading is the hot junction's temperature subtracts the cold junction's temperature. The compensator gives an ideal temperature in thermocouple's cold junction and improves the temperature reading 5~10^0C. For the second error, we adopted the float number in reading and recording the temperature value in the PLC program, it will improve the temperature reading 0~1^0C. For the last error, we have adopted two adjustable resistors, as described in chapter 3. Without the adjustable resistors, the power in the baking-box is changed 330W step by step, and now it can change by any value and can make the temperature change more slippier.

5. Summary

The PEFP FPC's baking process and baking arithmetic are introduced in this paper. The PLC module's wiring is designed. In order to make the baking-box' temperature change according to the required temperature-time curve, three different arithmetic are designed. After that, the error analysis and correction methods are introduced. All the baking system including the hardware and software is now completed and has been verified.

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