ARM-BASED CONTROLLER OF POWER SUPPLY FOR FOCUS SOLENOID OF KLYSTRON*

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Abstract

Klystrons are widely used in accelerators to provide powerful microwave power to the accelerating structure of linac to accelerate particles. The stability of a klystron is affected by the beam quality of high voltage gun of the klystron. The focus solenoid is needed to provide focus magnetic field around the klystron. ARM-based high performance of current stability power supply is designed to improve the quality of focus magnetic field of klystron, with a two-loop-hybrid design, which could achieve fast dynamic response and high static stability performance, instead of analogue power supply design. The bench test of the ARM-based controlled is done and the commissioning of the controller needs to be done in future study.

INTRODUCTION

HLS-II is upgraded by 2014, a synchrotron light source with a storage ring of circumference of 66.13 meters [1]. After upgrade, the linac of HLSII is 800MeV instead of 200MeV before upgrade. The layout of 800 MeV linac is shown as figure 1, consists of an electron gun, RF accelerating structure sections, microwave power supply system, and transportation line etc. 8 Klystrons, including two sets 80MW and six sets 50MW, are installed in HLS-II to provide microwave power to the accelerating structure via waveguide.
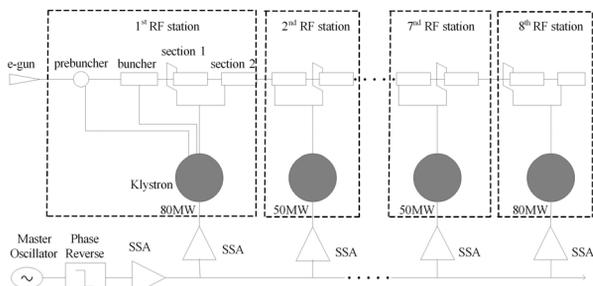

Figure1: Layout of 800 MeV linac of HLS-II.

Klystron is widely used in high energy physics accelerator, high power radar transmitter and communication industry, for its obvious merit, such as: high power, high gain, high stability, long life time etc. The microwave power output stability of the klystron is influenced by the beam quality of the electron bunch of high voltage gun of klystron, and high performance of

current stability power supply is needed to improve the quality of focus magnetic field. The power supply system of the klystron of HLS-II is shown as figure 2.

Figure 2: The power supply system of the klystron of HLS-II.

130MW modulator is the power supply for the klystron, and focus solenoid is at the output of the klystron, whose power supply is on the rack at the right side. The stability of focus magnetic field, which improves the microwave output quality of the klystron, is determined by the focus solenoid power supply. An ARM-based control module for focus solenoid is developed to replace the analogue control module in use, to simplify the system architecture and to improve the precision of current stability. The system design and bench test result of ARM-based controller are presented in this article.

THE ARM-BASED POWER CONTROLLER FOR FOCUS SOLENOID

The power supply of focus solenoid of klystron, with a parameter of 35V/35A, is a typical DC magnet small power supply, widely used in accelerators. Current control loop is usually used for this kind of power supply [2], and a two-loop-hybrid design is developed to improve the performance of focus solenoid power supply.

Topology of Controller

Two-loop-hybrid current-stabilized power supply includes an analogue loop and a digital loop, and its basic topology is shown as figure 3: (1) Adjustable AC-DC analogue voltage-stabilized switch power supply; (2) Load (focus solenoid); (3) Current sensor; (4) Control Module; (5) Auxiliary power supply.

The analogue loop is achieved by a commercial custom 35V/35A voltage-stabilized power module with PFC (power factor correction), and it is an analogue power supply with fast loop to compensate the variation of input AC power supply with high loop-bandwidth and high stability performance. The digital loop is a current-stabilized circuit to compensate the temperature

variation and load variation. The two-loop-hybrid design avoids complex high speed PWM type power supply design, and could achieve fast dynamic response and high static stability performance.
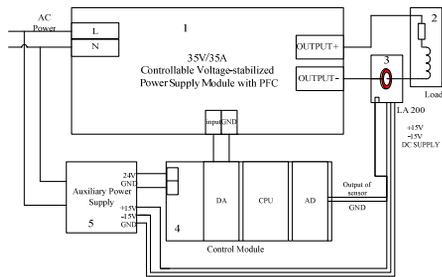

Figure 3: Basic topology of two-loop-hybrid current-stabilized power supply.

Current sensor is Hall type LA 200, detecting the output of the voltage-stabilized power supply, and its output is voltage signal, suitable for ADC sampling. The control module samples the output of LA 200 and compared with the set value to calculate the PID control value which is output by DAC to drive the control interface of voltage-stabilized power supply.

ARM-based Controller

Instead of analogue controller in use, an ARM-based control module is developed to increase the precision and flexibility, which is shown as figure 4.
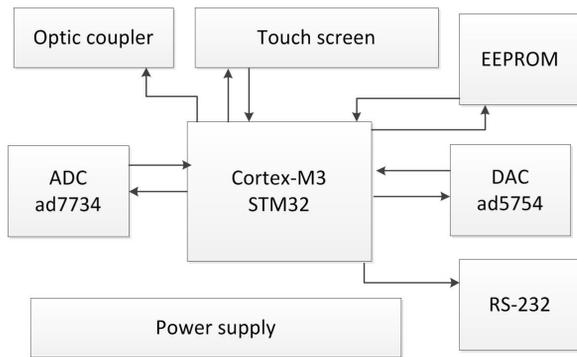

Figure 4: The scheme of ARM-based control module.

ARM is suitable for develop control module with different peripheral. STM32F103 is a 32bit Flash microcontroller based on the ARM Cortex-M3 processor from STMicroelectronics，combining high performance, real-time capabilities, digital signal processing, and maintaining full integration and ease of development. AD7734 is a 4-channel, +/-10V input range, high throughput, 24-bit sigma-delta ADC. AD5754 is a 4-channel, programmable output range (maximum +/-10.8V), 16-bit, DAC. The basic design for this module: Two digital PID loop to have ability to control two voltage-stabilized module of one ARM-based control module. So 2 channels of AD7734 are used for PID control, and the other 2 channels are used for monitoring. The PID loop is an interrupt type, with period adjustable

function from 0.2ms-2ms, and AD7734 can be configured via a simple digital interface, which allows users to balance the noise performance against data throughput up to 15.4 kHz. One RS-232 interface is used for upper computer communication. Optic coupler is used for digital input and output for system control with electro isolation. A touch screen is used for setting parameters for local users.

The PID calculation is processed in ARM STM32, and increment arithmetic algorithm is used. Discretized transfer function of increment arithmetic is as the equation below [3]:

$$G(z) = \frac{b_0 z^2 + b_1 z + b_2}{z^2 - z}; \qquad (1)$$

Where $b_0 = K_P + K_I + K_D$, $b_1 = -K_P + K_I - 2K_D$, $b_2 = K_D$. K_P, K_I, K_D is the adjustment value of portion, integral and differential. The flow diagram of PID calculation of ARM is shown as figure 5.
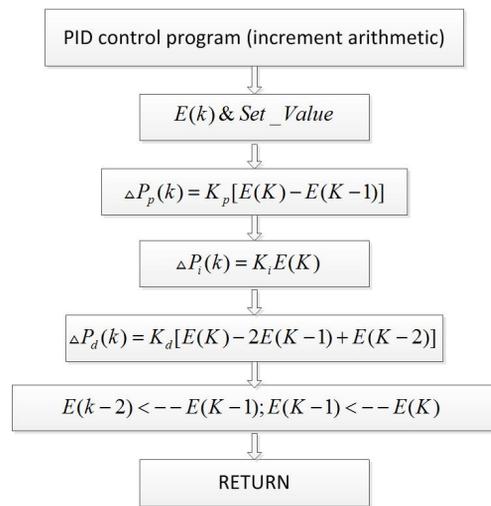

Figure 5: Flow diagram of PID calculation of ARM.

GUI Design and Functionality

The calibration function is developed for ADC input and DAC output of the ARM-based controller. When standard calibrated voltage is input to ADC, the GUI on touch screen has the function of calibrating the voltage coefficient of every channel of ADC data. And so does the voltage coefficient of DAC, by high precision multi-meter measuring at the output of the DAC. Parameters of the PID could be set via tough screen, such as: K_P, K_I, K_D and PID period. The input range of ADC could be selected via GUI: -10V/-5V/0~5V/10V. Self-testing function, alarm function, and RS-232 communication function is integrated with the software of the ARM-based controller.

BENCH TEST

The DAC output stability of ARM-based controller is tested by Keithley 8_1/2-Digit multimeter. The result is shown as figure 6, about 4 ppm.
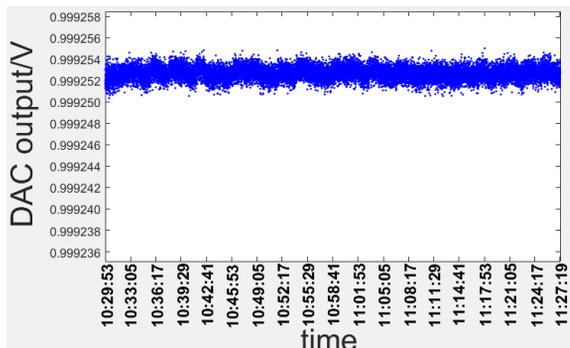

Figure 6: Test result of DAC of controller.

For short of standard voltage calibration source, the test of ADC stability is done as: DAC output is put directly into ADC of the controller by a cable. And the measurement result of the test is shown as figure 7.
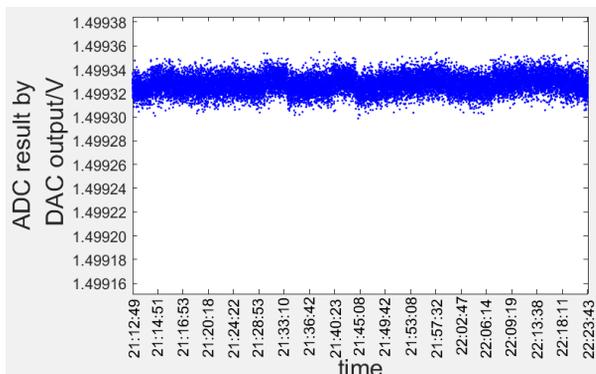

Figure 7: Test result of ADC by DAC output.

The ADC stability with DAC output is about 35 ppm, due to the electro-magnetic affection of the long cable. Even though, the ADC result is good enough for focus solenoid power supply control.

The PID stability is tested when DAC output is put into ADC input of the controller, and the ADC value is shown as figure 8 when PID calculation is carried out. The stability of the test is about 1.3×10^{-4}.
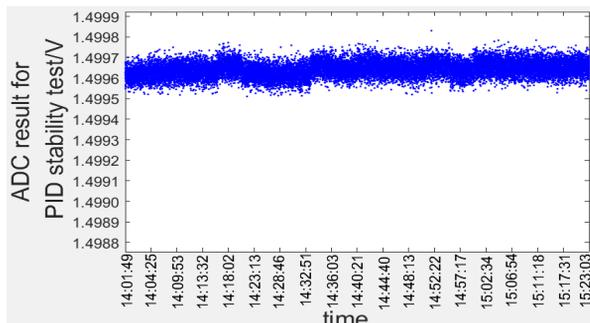

Figure 8: test results of PID stability.

SUMMARY

An ARM-based power supply controller is developed at HLS-II for focus solenoid of klystron for linac. The bench test has been done, and the commissioning of the power supply controller will be done soon for the klystron.

ACKNOWLEDGEMENTS

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