FEEDBACK CONTROL OF 50HZ POWER SUPPLY

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ABSTRACT

Both pulse and dc-bias power supplies for the fast cycling synchrotron can be controlled by the ac and dc magnetic field generated in its load magnet. For this the real field strength is compared with the excitation data which is compiled in the control computer and the reference current signals are modified every time when the field is measured. To make the magnetic field accurately enough, an averaging method for the repetitive field measurements is implemented. As the feedback is made at certain intervals, the discontinuous feedback control is treated from the view point of current stability.

1 INTRODUCTION

A high repetition mode power supply has been developed to study the feasibility of a rapid cycling synchrotron and to investigate the behavior of its magnet excitation [1][2][3]. The power supply set is composed of a dc power supply for the bias field and a pulse power supply for ac excitation (Fig.1). A basic accelerator frequency, namely the resonant frequency of magnet network is

$$f_0 = \frac{\omega_0}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{2L_{ch}+L_m}{L_{ch}L_m(C_1+2C_2)}} = 50\text{Hz}. \quad (1)$$

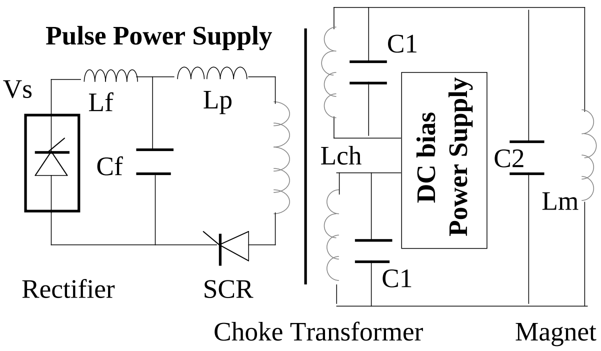

Figure: 1 Configuration of rapid cycling synchrotron power supply.

The filter circuit has a resonant frequency of 12.5Hz for voltage charging and discharging, i.e.

$$f_f = \frac{\omega_f}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{1}{L_f C_f}} = 12.5\text{Hz}, \quad (2)$$

and the pulse circuit has a resonant frequency of 150Hz, i.e.

$$f_p = \frac{\omega_p}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{1}{L_p C_f}} = 150\text{Hz}. \quad (3)$$

A half cycle current pulse is generated at the SCR turn-on frequency of 50Hz to compensate the power loss in the resonant network. According to the measurement of the magnet resonant network, a quality factor (Q) of about 80 is obtained [1].

The dc bias power supply is a 12-pulse SCR rectifier with a transistor regulator in series. A current loop is applied for current stability while a voltage loop is used to assure the transistor bank operating in a linear region. In the pulse power supply, the source voltage V_S and SCR firing phase are regulated. Now magnetic field feedback for both dc and ac is implemented. Fig.2a and Fig.2b show the schematic circuits. This paper will concentrate description upon the magnetic field feedback.

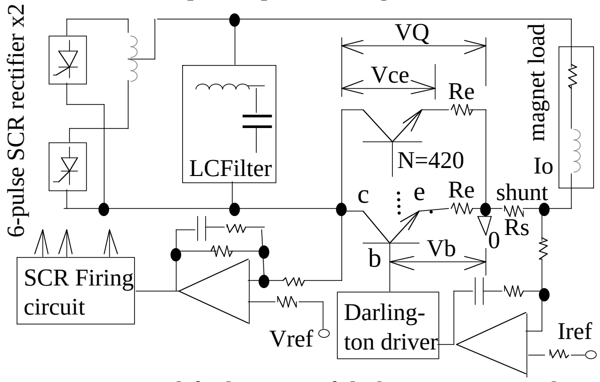

Figure: 2a Simplified circuit of dc-bias power supply.

2 FEATURES OF MODEL POWER SUPPLY SYSTEM

2.1 Magnetic field measurement

The magnetic field can be expressed as

$$B(t) = B_{dc} + B_{ac}\sin(\omega_0 t), \quad (4)$$

where $B(t)$: magnetic field strength
B_{dc}: dc magnetic field strength
B_{ac}: ac magnetic field strength
ω_0: angular frequency of ac field.

AC magnetic field is measured by integrating the alternate voltage induced in a static coil (S-coil). The S-coil induced voltage is [4],

$$e_S(t) = NA\frac{dB(t)}{dt} = NAB_{ac}\omega_0\cos(\omega_0 t). \quad (5)$$

Integrating at $\left[-\frac{T}{4},\frac{T}{4}\right]$, we get $E_S(t) = 2NAB_{ac}$, where N is the number of turns of the S-coil, A is its average area, and $T=2\pi/\omega_0$.

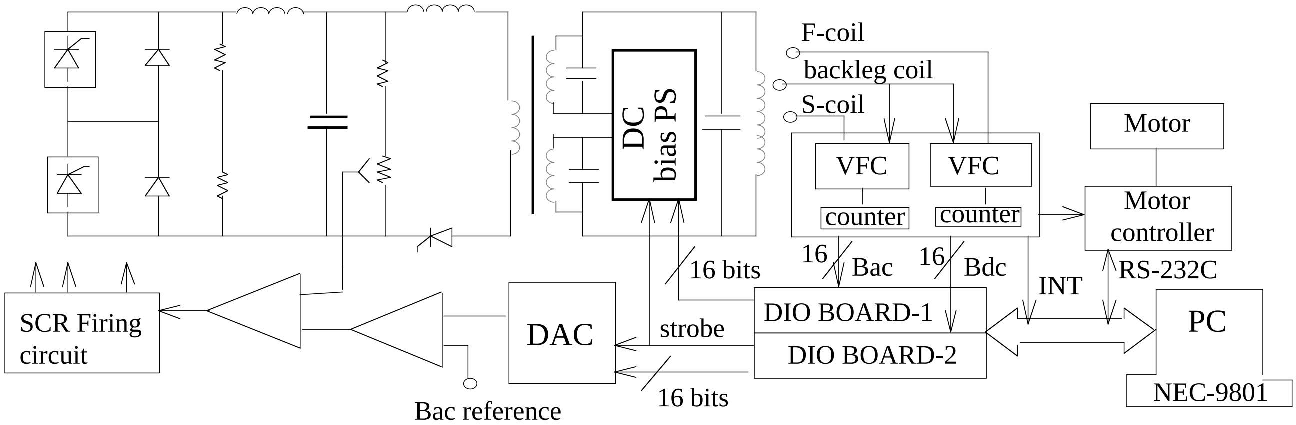

Figure: 2b Magnetic field feedback diagram for both power supplies (mainly for pulse power supply).

A flip coil (F-coil) with the same specifications is used to measure the dc field strength. The F-coil induced voltage is

$$e_F(t) = -NAB_{dc}\omega_f \sin(\omega_f t), \qquad (6)$$

where ω_f is the coil flip angular frequency. Integrating the induced voltage at $\left[0, \frac{T_f}{2}\right]$, we have

$$E_F(t) = -2NAB_{dc}. \qquad (7)$$

In measuring the fields, the induced voltages are applied to two VFC's (Voltage to Frequency Converter) for B_{dc} and B_{ac} independently, and the integration is carried out by counting the VFC output signals.

2.2 Modeling the discrete field feedback

The measured magnetic fields are read into personal computer in the forms of 16-bit data through DIO (Digital Input and Output) ports. To attain higher accuracy, the data are averaged for several measurements. The averaged data, used as the feedback signals, are applied discontinuously with the interval determined by an interruption subroutine. The operation is characterized by the sampled data feedback. Fig.3 shows the block diagrams.

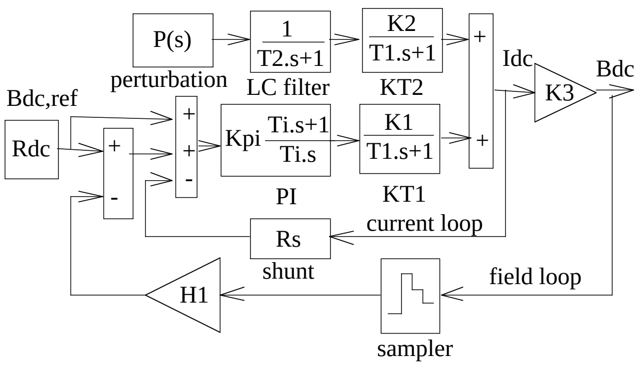

Figure: 3a DC-bias power supply feedback loops.

In Fig.3a, elements KT1 and KT2 represent the transfer function of magnet load and the transistor regulator in combination while the PI element is for current regulation. The current reference signal is refreshed at the rate of B_{dc} sampling. With the current loop only, a current stability of $\pm 6\text{x}10^{-5}$ is attained. After the field feedback was applied, the system response was studied in detail by either experiment and simulation.

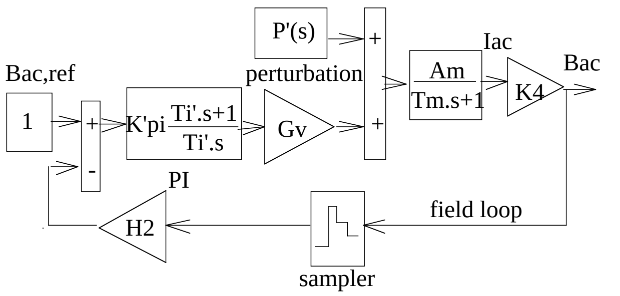

Figure: 3b Pulse power supply feedback loop.

In pulse power supply, the transfer function from the power source V_s to the resonant current I_{ac} amplitude is approximated by the first order lag element and can be expressed as

$$P(s) = \frac{A_m}{1+T_m s}, \qquad (8)$$

where $T_m = Q/\pi f_0$ and $A_m = 1/\pi f_0 L_m$. The voltage loop for V_s stabilization has a fast response characteristic and can be approximated to constant G_v in the B_{ac} loop.

2.3 System analysis and simulation

A detailed simulation of the dc-bias power supply indicates that by the magnetic field feedback the current and magnetic field stability can be improved with the averaging process.

3 PERFORMANCE

The ac and dc field probes are the search coils set parallel in the magnet gap. The dc probe rotates forward by 180 degrees and returns at an original position in 1 sec. Their induced voltages are integrated and fed to respective power supplies in digital signals. These feedback signals can be generated every 1 sec in the most frequent case. And the feedback interval can be controllable by suppressing the strobe signals. It results in also suppressing the motor drive signal for probe flip. This kind of control is realized namely by the feedback frequency controller. It determines the number of the successive field samplings at every 1 sec and the interval time waiting for the next sampling.

The experimental results for I_{dc}=200A are given in Fig.4 in which the current performances were recorded within the first several tens seconds after the field feedback applied.

Fig.4(a) shows the current I_{dc} variation of the feedback at every 1 sec. If the successive several field data are averaged and fed back once at fixed interval through an intermediate personal computer, the current regulation is improved remarkably as shown in Fig.4(d). Interval is selected between 1 and 9999 sec in 1 sec step. Fig.4(b) and (c) are 1 and 5 sampled data feedback for 20 sec interval. For the real synchrotron the current drifts by the gradual change of the environment, so the frequent feedback is not necessary but the accurate feedback signal is essential. The experimental results are in good agreement with those obtained by simulation as shown in Fig.5.

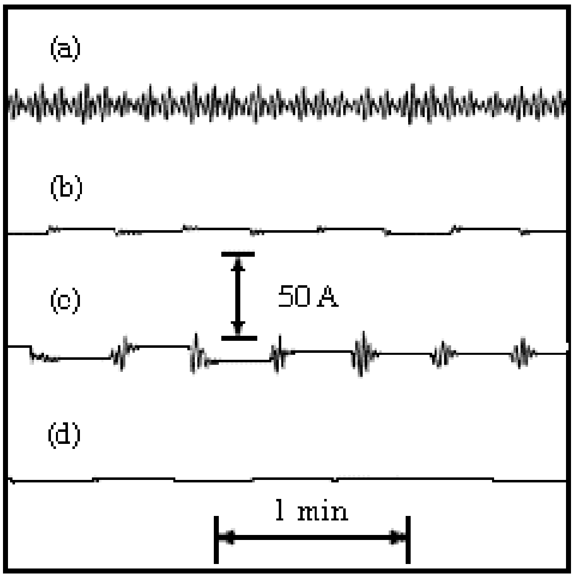

Figure: 4 (a) Current I_{dc} fluctuation by the frequent feedback of the magnetic field. The feedback interval is 1 sec. (b) 1 sampled data and (c) 5 sampled data feedback for 20 sec interval. (d) Current regulation by feedback averaged over 5 sampled data for 20 sec interval.

The performances concerning to the ac current and ac field are largely different from those of the dc power supply. Experiment and simulation are in progress.

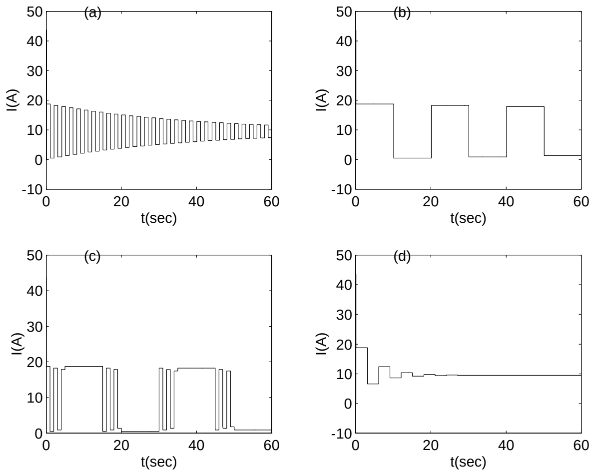

Figure: 5 Results of simulation of the dc-bias power supply. (a) corresponds to that in Fig.4. (b) and (c) are same as in Fig.4 except for the interval, 10 sec instead of 20 sec. (d) Feedback averaged over 3 sampled data for 3 sec interval. The vertical axis is current deviation from the simulation setting value of 750A.

4 CONCLUSION

The magnet field data are used as a feedback signal to power supplies of the rapid cycling synchrotron. As the field measurement takes about 1 sec at every time with the search coil, this system furnishes the discrete digital feedback control. Using together with the feedback frequency controller and data processing computer, more flexible and accurate current control can be attained.

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