EQUIVALENT TRANSFER FUNCTION GENERATOR OF MAGNET POWER SUPPLY USING DSP*

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Abstract

DC active filter is operating to reduce the current ripple of the KEK 12GeV PS main ring quadrupole magnet power supply. However, transient response restricts the effective area to alive the active filter during injection and extraction period since the transient response becomes oscillatory with decreasing amplitude. In order to operate the active filter for all period, the real ripple component except transient response signal should be detected. Equalizer, which made it possible to realize the equivalent transfer function using DSP (Digital Signal Processor), will assist to reject the transient response. General description of the DSP control system, algorism, electric devices and experiment performance of equalizer will be presented

1 INTRODUCTION

Power supply for the KEK 12GeV PS main ring quadrupole magnets is twelve-phase thyristor (SCR) converter[1]. Ripple of the power supply theoretically contains 600 Hz and higher harmonic components. In actual operation, the uncharacteristic ripples of 50 Hz, 100 Hz and those harmonics are considerably induced due to the fluctuation of ignition angle on the SCR converter and the three-phase unbalance[2]. These ripples modulate the extracted beam spill during slow beam extraction. Ripples should be decreased less than 10^{-5} to 10^{-6} of the direct current for the beam spill quality requirement.. Passive filters, comprises of low pass filter and several resonance filters, were set up to reduce these ripples[1]. The low pass filter has the cut off frequency of 55 Hz. Active filter should work for reduction the rather lower frequency ripples.

Ripple signal from the voltage ripple detector, the low impedance resistive voltage divider, include the transient response due to the fundamental voltage pattern as shown in Fig.1. In order to reduce this transient signal, detected signal sends to power amplifier through the first order filter and dead time transfer function. However, the large transient signal still remains. The active filter is so far turned off at the transient period by the gate signal. The recent developed digital signal processor (DSP) is promising for the application of the equivalent transfer function (equalizer) from the SCR converter to the ripple detector. The spill feed back system by the DSP[3] was

also made it possible and then tried to make an equalizer system. In this report, general description of the system, hardware and the experiment results will be described.
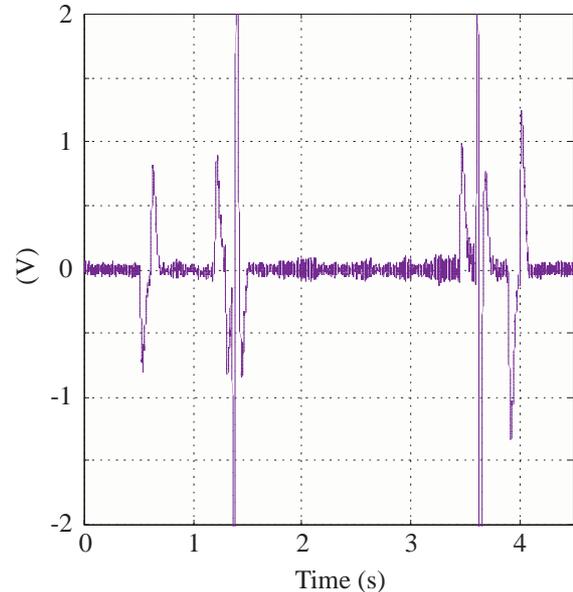

Figure 1: Ripple signal from the voltage ripple detector, the low impedance resistive voltage divider, include the transient response due to the fundamental voltage pattern.

2 SYSTEM DESCRIPTION AND HARDWARE

KEK 12GeV PS main ring quadrupole magnets comprises of a twelve-phase thyristor (SCR) converter, a passive low pass filter and an active filter. Detected voltage ripple signal after the low pass filter is fed to the primary of the reactor transformer through the high pass filter and the power amplifier to reduce the current ripple of the load magnets as shown in Fig.2. Voltage ripple signal after the high pass filter includes the transient response from the derivation of the fundamental voltage pattern. Figure 3 indicates the voltage pattern. The ignition pulse through the APPS (Automatic Pulse Phase Shifter) fires the SCR converter by the output pattern from the control computer. We designed the equivalent transfer function generator by using the recent developed DSP on the VME board. Figure 4 shows the flow of the transfer function. Transfer function E(s) is the equalizer

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made by DSP and subtracts by the detected voltage signal, then only transient signal should be cancelled. Figure 5 shows the block diagram of the power supply system using DSP (Motorola 56301) which is operated by 50 MHz, that is, 20 μs sampling clock. The pattern signal from the control computer is fed to the DSP through the 12 bits A/D converter and out through the 16 bits D/A converter. Output signal is proceeded by offset and gain tuner and subtracted by the detected signal and then fed to power amplifier.
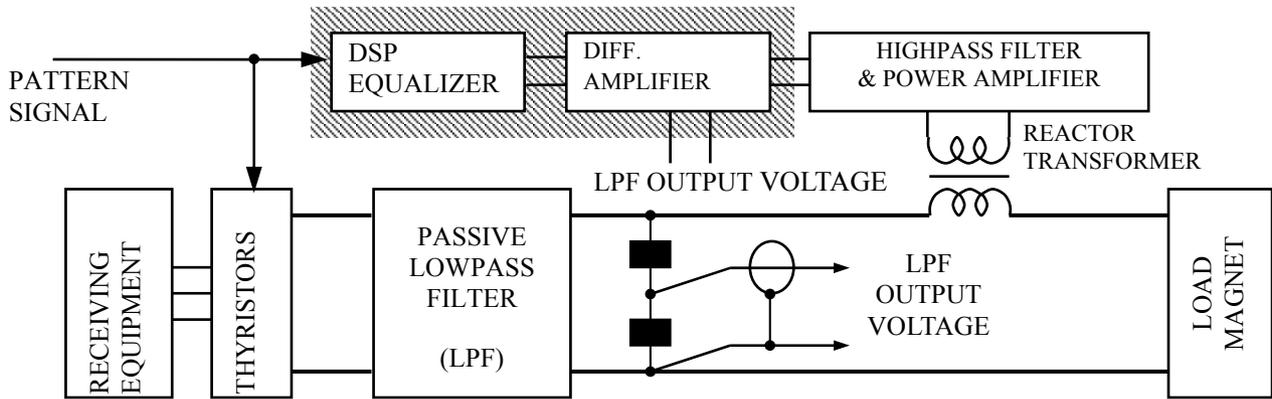

Figure 2: Block diagram of the KEK 12GeV PS main ring quadrupole magnets power supply system. Hatched parts are equalizer.
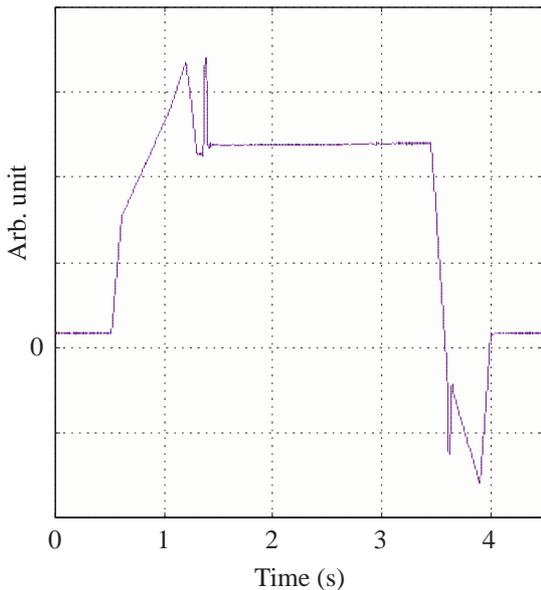

Figure 3: The voltage pattern of the focusing quadrupole magnet power supply. The horizontal betatron tune should be close to half integer at the beginning of the beam extraction. The spike like pattern at the flat top start is caused from this operation schema.
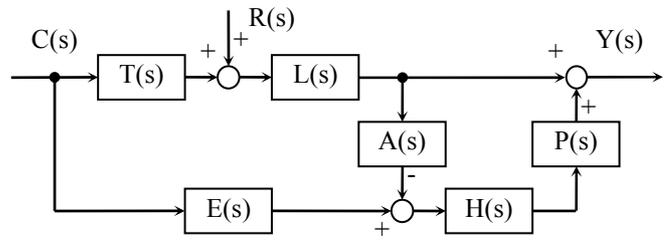

Figure 4: Flow of the transfer function.

C(s): voltage pattern from computer
T(s): thyristor rectifier
R(s): ripples from thyristor rectifier and
     external transmission line
L(s): transfer function of passive lowpass filter
A(s): attenuator (1/100)
E(s): DSP equalizer (feed forward controller)
H(s): transfer function of active highpass filter
P(s): power amplifier
Y(s): voltage of the load electromagnet

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┌──────────────┐  ┌──────────────────────┐   ┌──────────────┐  ┌──────────┐  ┌──────┐
│   PATTERN    │  │  DSP(MOTOROLA 56301)  │   │     LPF      │  │  DIFF.   │  │      │
│   SIGNAL     │  │  CLOCK: 50 MHz        │   │   OUTPUT     │→ │  AMP.    │→ │  HP  │
│              │  │  20 μs clock          │   │              │  │          │  │      │
└──────────────┘  └──────────────────────┘   └──────────────┘  └──────────┘  └──────┘
        │
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┌──────────────┐  ┌──────────────┐  ┌──────────────┐  ┌──────────────┐  ┌──────────────┐
│   12 bit     │  │   DIGITA     │  │   EQUIVA-    │  │   16 bit     │  │  OFFSET &    │
│   ADC        │→ │   L          │→ │   RENT LPF  │→ │   DAC        │→ │  GAIN        │
└──────────────┘  └──────────────┘  └──────────────┘  └──────────────┘  └──────────────┘
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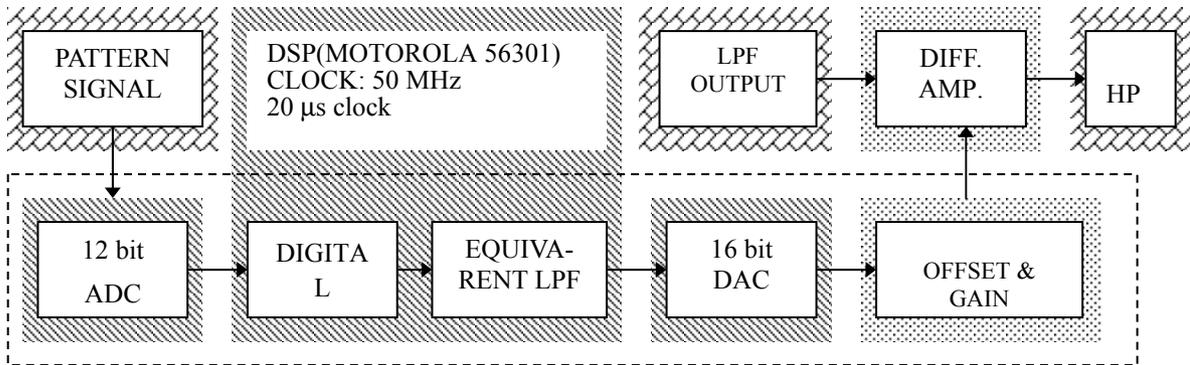
Figure 5: Block diagram of the power supply system using DSP (Motorola 56301) which is operated by 50 MHz, that is, 20 μs sampling clock.

3 EXPERIMENT RESULTS

In order to obtain the slow extracted beam, half integer resonance is utilized, then the horizontal betatron tune should be close to half integer at the beginning of the beam extraction. The spike like pattern at the flat top start is caused from this operation schema as shown in Fig.3 which shows the voltage pattern after the low pass filter. This spike like pattern becomes the origin of large transient signal as shown in Fig.1. The experiment has performed for the focussing quadrupole magnet power supply on the operation of 4sec repetition. Figures 6 shows the voltage patterns of equalizer out. Voltage ripple obtained the difference between the signals of Figure 3 and 6. Transient part has reduced extremely as shown in Fig.7. Operation of the active filter using this voltage ripple signal was performed for a short time, an active filter can be operated during whole period without gate signal, but the reduction ratio of the ripple was rather smaller than the conventional schema. We are considering that the origin is caused from the fluctuation of the phase of the differentiated signal. Further investigation to solve this problem will be required.

4 REFERENCES

[1] Performance of the Main Ring Magnet Power Supply for the KEK 12 GeV Proton Synchrotron, H.Sato, et al., IEEE Transaction on Nuclear Physics, NS39(1992)1490

[2] Reduction of the Uncharacteristic Ripple Component in the Synchrotron Power Supply, H.SATO, et al., Conference Records of the IEEE Nuclear Science Symposium, Orlando,Florida, Oct. 1992, p.569.

[3] Slow Extraction Control Using the Digital Feedback Systems, H.Nakagawa, et al., Proc.of the 2000 European Particle Accelerator Conference, 26-30 June 2000, Austria Center Vienna, p.192
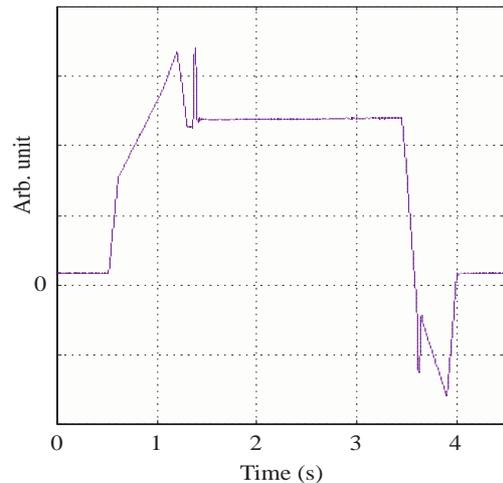
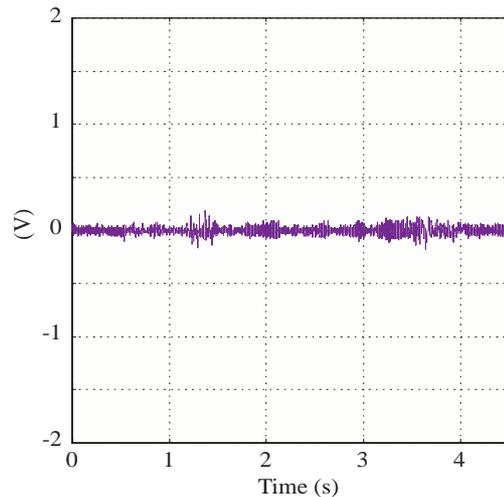Figure 6: Voltage patterns of equalizer out.

Figure 7: Voltage ripple signal from the differenciation between the detected voltage and the equalizer out. Transient part has reduced extremely.