A Study on High Performance Power Supply for an Accelerator

H. Taura,[a] S. Ninomiya,[a] T. Saito,[a] and K. Sato[a]

[a] *Research Center for Nuclear Physics (RCNP), Ibaraki, Osaka 567-0047, Japan*

A power supply is one of the most important elements for an accelerator, and its stability and noise level have been found out to be very important for an opperation of an accelerator. Recently, common mode noise to the current have been noticed and its countermove has been done. At HIMAC(Heavy Ion Medical Accelerator in Chiba) the power supply which has not only a normal-mode filter, which is ordinarily equipped with a power supply for an accelerator, but also a common-mode filter was constructed and its current noise is less than 1 ppm. Even though effect of a common-mode filter have already shown theoretically by Kumada[1], clearly more theoretical and experimental studies are needed. Especially, no direct measurements of the effect of the common-mode filter were carried out, because the filter was designed to be fixed in the power supply.

As is already shown[1], 6-terminal circit should be considered for a power supply, which has four variables as (1)a voltage of the going signal line to the earth(V), (2)a voltage of the coming signal line to the earth($-U$), (3)a current of the going signal line to the load(I) and (4)a current of the coming signal line from the load(J). Hereafter, we use another set of the variables, i.e., $V+U$, $I+J$, $V-U$ and $I-J$. In a physical meaning, the variable $V+U$ represents the potential difference between PN signal line. The transfer equation is represented as

$$\begin{pmatrix} V_o+U_o \\ I_o+J_o \\ V_o-U_o \\ I_o-J_o \end{pmatrix} = \mathcal{T} \begin{pmatrix} V_i+U_i \\ I_i+J_i \\ V_i-U_i \\ I_i-J_i \end{pmatrix}, \tag{1}$$

where $\mathcal{T}$ is a 4x4 transfer matrix and i and o mean input and output, respectively. We found that the matrix $\mathcal{T}$ is a so-called sympletic matrix which has been studied for a beam physics[2]. Generally, N-terminal circit consisting of $N/2$ inputs and $N/2$ outputs is represented as a $2(N-1)$-dimensional sympletic group.

When the circit has complete symmetry, the transfer matrix $\mathcal{T}$ for a 6-terminal circit can be parametrize as

$$\mathcal{T} = \mathcal{T}_0 = \begin{pmatrix} \mathcal{A}_0 & 0 \\ 0 & \mathcal{B}_0 \end{pmatrix}, \tag{2}$$

where$\mathcal{A}_0$ and $\mathcal{B}_0$ are 2x2 sympletic matrixes. In this case, two parameter sets, $(V+U, I+J)$ and $(V-U, I-J)$ are independent. That is, when we measured the potential difference between PN signal line, only normal mode ripple is observed.

When the symmetry is broken, the transfer matrix $\mathcal{T}$ is represented by

$$\mathcal{T} = \begin{pmatrix} I\cos\phi & \mathcal{D}^{-1}\sin\phi \\ -\mathcal{D}\sin\phi & I\cos\phi \end{pmatrix} \begin{pmatrix} \mathcal{A} & 0 \\ 0 & \mathcal{B} \end{pmatrix} \begin{pmatrix} I\cos\phi & -\mathcal{D}^{-1}\sin\phi \\ \mathcal{D}\sin\phi & I\cos\phi \end{pmatrix}, \tag{3}$$

or

$$\mathcal{T} = \mathcal{R} \begin{pmatrix} \mathcal{A} & 0 \\ 0 & \mathcal{B} \end{pmatrix} \mathcal{R}^{-1}, \tag{4}$$

where I is a 2x2 unit matrix, $\mathcal{A}, \mathcal{B}, \mathcal{D}$ are 2x2 sympletic matrixes and $\mathcal{R}$ is a 4x4 sympletic rotational matrix[2]. In this case, when we measured the potential difference between PN

signal line, not only normal mode ripple but also common mode ripple should be observed. Generally it is rather difficult to construct a power supply with complete symmetry and, therefore, more or less, common mode ripple should be present.

A 3kA-250V power supply of twelve pulses thyristor type with a common mode filter have been constructed. In this power supply, since the common mode filter can be easily removed, the effect of the common mode filter can be directly studied. The ripple amount is ~50 ppm and the DC stability is $\sim 2 \times 10^{-6}$, respectively, which are quite well for a power supply without any active filter.

Current ripple was measured both with and without the common-mode filter. For normal mode ripple, there were no differences between the presence and the absence of the common-mode filter within 10%. On the other hand, the common mode ripple without the common-mode filter was 20%-50% larger than that with the filter. The DC stability is, however, almost the same both with and without the common-mode filter. Measurements of the decline ratio of the common mode ripple by the common-mode filter as a function of the frequency show us that the common mode ripple is generated not at the load side, but at the power supply side. In other words, asymmetry is present in the power supply.

Quantitative analysis has, however, not succeeded yet, because the circit system in the power supply is rather complicated and difficult. For more detailed discussions, clearly more experimental results are needed.

References

[1] M. Kumada, Doctor thesis, Department of Accelerator Science, Graduate University for Advanced Studies (1996).

[2] D. A. Edwards and L. C. Teng, IEEE Transaction on Nuclear Science **NS-20** (1973) 885.