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Synchronization Phenomena and Oscillation Death of Star-Coupled van der Pol Oscillators with Additional Oscillators

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1 Introduction

In this study, we investigate star-coupled oscillators with additional oscillators with different frequency. We change the value of frequency of the additional oscillators and investigate the effect to the synchronization phenomena of star-coupled oscillators.

2 Circuit Model

Figure 1 shows the system model in this study. We change the frequency ω and investigate the influence of the 5th oscillator for the overall star-coupled circuit.

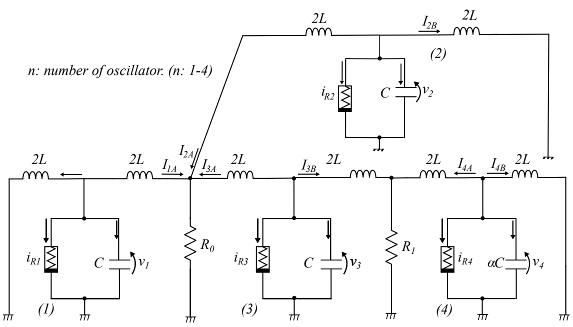

Fig. 1 Circuit model.

Three van der Pol oscillators are connected as the star combination. In addition, we add a different frequency oscillator to the star-coupled van der Pol oscillators. We change the frequency of the $4th$ oscillator and investigate the influence of the $4th$ oscillator to the overall star circuit.

First, the $v - i_{Rk}$ characteristics of the nonlinear resistors are defined as follows:

$$i_{Rk} = -g_1 v_k + g_3 v_k^3. \quad (1)$$

The normalized circuit equations are represented as follows:

$$\begin{cases} \frac{dx_k}{d\tau} &= \varepsilon(x_k - \frac{1}{3}x_k^3) - y_k - z_k \quad (k = 1, 2, 3) \\ \frac{dy_k}{d\tau} &= \frac{1}{2}x_k - \frac{1}{2}\delta_0(y_1 + y_2 + y_3) \quad (k = 1, 2, 3) \\ \frac{dz_k}{d\tau} &= \frac{1}{2}x_k \quad (k = 1, 2, 4) \\ \frac{dz_3}{d\tau} &= \frac{1}{2}x_3 - \delta_1(z_3 + y_4) \\ \frac{dx_4}{d\tau} &= \omega^2(\varepsilon(x_4 - \frac{1}{3}x_4^3) - y_4 - z_4) \\ \frac{dy_4}{d\tau} &= \frac{1}{2}x_4 - \frac{1}{2}\delta_1(z_3 + y_4). \end{cases} \quad (2)$$

3 Simulation Result

The amplitudes of the oscillator are shown in the Figs. 2 and 3 . In Fig. 2, ω is changed inside a large range value [1.0, 2.0]. As the result, the amplitudes of the $1st$ oscillator are changed by ω for $1.0 < \omega < 1.3$. When ω above 1.3, the amplitude of the $1st$ oscillator and the $2nd$ oscillator are nearly constant.

In Fig. 3, when the ω increase from 1 to 1.2, the amplitudes of the $3rd$ and the $4th$ oscillator become gradually smaller. Next, when the ω is increased to 1.4, the amplitudes of the $3rd$ and the $4th$ oscillator are perfect stop. When ω above 1.4, the amplitudes of the $4th$ oscillator go on increasing. However, the amplitudes of the $3rd$ oscillator are almost unchanged.

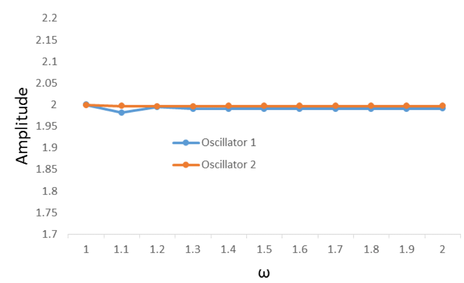

Fig. 2 Amplitude of oscillator 1 and oscillator 2.

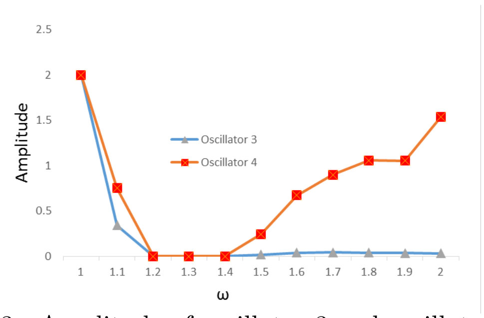

Fig. 3 Amplitude of oscillator 3 and oscillator 4.

4 Conclusion

We have investigated synchronization phenomena and oscillation of five oscillators with different frequencies. By carrying out computer simulations, we have confirmed that oscillation of the $3th$ and the $4th$ oscillators are death by increasing ω.