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Synchronization in Coupled Oscillators Containing Ring and Star Structures

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1. Introduction

Analysis of synchronization phenomena is expected for applying in various fields. In this study, we investigate synchronization phenomena observed in the system model containing ring and star. In addition, we observe several types of synchronization phenomena by increasing the coupling strength of ring.

2. System model

Figure 1 shows a system model constituted van der pol oscillators (VDP-A and VDP-B). In this study, the number of VDP-A and VDP-B is set to 1 and 5. VDP-A is the only one central circuit which is connected to all VDP-B in this system.

The charactaristic of ring coupling has in-phase, anti-phase and N-phase. The charactaristic of star coupling has in-phase and anti-phase. The normalized equations of VDP-A circuit are given as follows:

$$\begin{cases} \dot{x_c} = \alpha x_c(1 - \frac{1}{3}x_c^2) - y_c + \beta\{Nx_c - \sum_{n=1}^{N} x_n\}, \\ \dot{y_c} = x_c, \end{cases} \tag{1}$$

where N denotes the number of VDP-B.

On the other hand, VDP-B are connected to the adjacent VDP-B and VDP-A. The normalized equations of VDP-B circuit are given as follows:

$$\begin{cases} \dot{x_n} = -y_n - z_n - \beta(x_c - x_n) + \alpha x_n(1 - \frac{1}{3}x_n^2), \\ \dot{y_n} = \frac{1}{2}\{x_n - \gamma(y_n + z_{n+1})\}, \\ \dot{z_n} = \frac{1}{2}\{x_n - \gamma(z_n + y_{n-1})\}, \end{cases} \tag{2}$$

where $n = 1, 2, 3...N$, $z_{N+1} = z_0$ and $y_0 = y_N$.

The parameters α, β and γ denote the coupling strength of the inductor L, resistor R and resistor R_0.

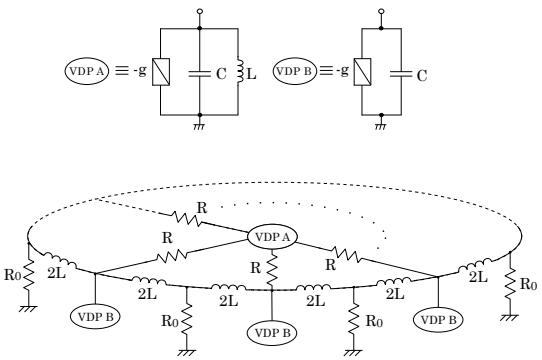
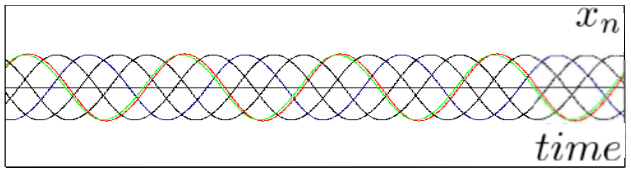


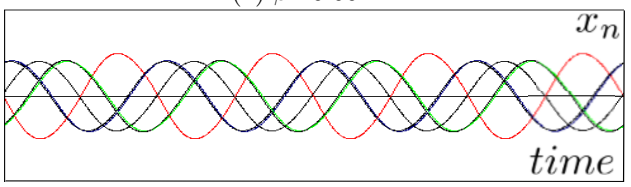
Figure 1: system model.

3. Simulation Results

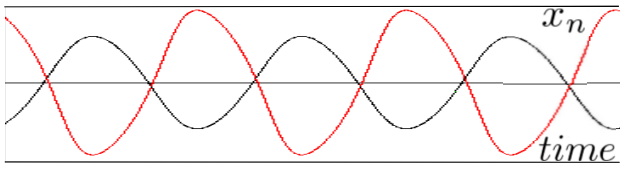
The simulation results of the system model containing six circuits are shown in Fig. 2. The value of the parameters are fixed with β=0.001, 0.0085 and 0.05. In the case of β=0.001, 5 phase synchronization appeared because the coupling strength of VDP-A is weak. When the value of β sets 0.0085, some time wave forms of VDP-B come close on in-phase synchronization. In the case of β=0.05, 5 phase synchronization become in-phase synchronization. And then VDP-A becomes anti-phase synchronization with VDP-B by increasing the value of β.



(1) β=0.001.



(2) β=0.0085.



(3) β=0.05.

Figure 2: Simulation Results for N=6 (α = 0.1 and γ = 0.02).

4. Conclusions

In this study, we have proposed a system model using six circuits that is combined the ring and star structures. We have observed the synchronization phenomena by increasing the coupling strength of ring. When the coupling strength is sufficiently small, system model becomes like function of ring coupling therefore, 5 phase synchronization can be observed. By increasing the coupling strength, time wave forms of VDP-B have come close in-phase synchronization. When the coupling strength is sufficiently large, time wave forms of VDP-A and VDP-B become anti-phase synchronization. In the future, we investigate synchronization phenomena using other circuits.