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Stability analysis method of a PV-fed boost converter

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Abstract— It is well known that the bifurcation phenomena occur in dynamical systems. However, the bifurcation analysis is still insufficient for a PV-fed boost converter. Hence, this paper proposes a stability analysis method for the converter as the first step of the bifurcation analysis.

1. Introduction

A PV-fed boost converter is a topic of extensive research[1]. However, there has yet to be a study on methods for deriving the bifurcation point for the converter. On the other hand, we have established a bifurcation point derivation applicable to various systems based on the stability analysis on their Poincare maps. Therefore, the study proposes the stability analysis method for the PV-fed boost converter required in the first step of the bifurcation point derivation.

2. PV-fed boost converter

Figure 1 shows the circuit diagram of the PV-fed boost converter. The circuit equations and the current-voltage characteristics of the solar cells are written as follows:

$$\text{If the switch is ON : } \begin{cases} L\dfrac{di_L}{dt} = v_L \\ C\dfrac{dv_o}{dt} = -\dfrac{v_o}{R} \end{cases}, \quad (1)$$

$$\text{If the switch is OFF : } \begin{cases} L\dfrac{di_L}{dt} = v_L - v_o \\ C\dfrac{dv_o}{dt} = i_L - \dfrac{v_o}{R} \end{cases}, \quad (2)$$

$$I_{ph} - I_0\left(e^{A(v_L+i_LR_s)} - 1\right) - \frac{v_L + i_LR_s}{R_{sh}} - i_L = 0, \quad (3)$$

where (i_L, v_o, v_L) are state variables.

Here, we derive ordinary differential equations (4) and (5) of v_L by differentiating Eq. (3) by t because Eq. (3) is described as the implicit function and makes the analysis difficult.

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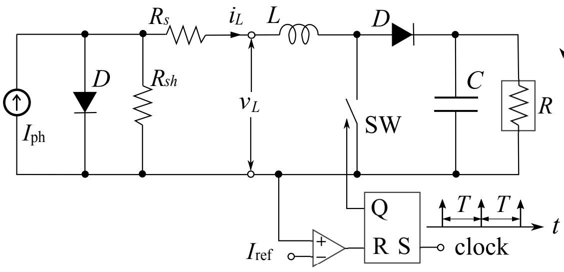

Figure 1: PV-fed boost converter

If the switch is ON :

$$L\frac{dv_L}{dt} = -\left(R_s + \frac{R_{sh}}{R_{sh}I_0Ae^{A(v_L+i_LR_s)} + 1}\right)v_L \quad (4)$$

If the switch is OFF :

$$L\frac{dv_L}{dt} = -\left(R_s + \frac{R_{sh}}{R_{sh}I_0Ae^{A(v_L+i_LR_s)} + 1}\right)(v_L - v_o) \quad (5)$$

Hence, we can describe the converter only with the ODEs but without the implicit function. In other words, we can calculate the stability using Eqs. (1), (2), (4), and (5).

3. Stability analysis

The conditional expression of a fixed point and its characteristic equation are described as:

$$M(i_{L0}, v_{o0}, v_{L0}) - (i_{L0}, v_{o0}, v_{L0}) = 0, \quad (6)$$

$$\det\left(\frac{\partial M}{\partial(i_{L0}, v_{o0}, v_{L0})} - \mu \boldsymbol{I}_3\right) = 0. \quad (7)$$

(i_{L0}, v_{o0}, v_{L0}) are the initial values and M is the Poincaré map, defined by the stroboscopic map of the solution trajectory discretized with the period T. The bifurcation phenomena occur when the characteristic multipliers cross the unit circle in the complex plane by changing the parameters, then the nature of the fixed point changes. This study numerically calculates the stability by solving Eq. (7) and obtaining the characteristic multipliers μ.

References

[1] B. Hayes, *et al.*, "Application of the Filippov Method to PV-fed DC-DC converters modeled as hybrid-DAEs," Engineering Reports, Vol. 2, e12237, 2020.