Paris Session 2022

Harmonic Calculation Considering Inverter-Based Resources (IBRs)

C4, PS1

Question 2: What are the experiences on harmonic instability associated with IBRs in AC power systems? Can the phenomena be reliably predicted using the existing modelling and analysis methodologies, paying attention to data requirements and possible improvements for the future?

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Motivation

- In recent years, with the development of inverter technology, in addition to conventional rectifiers, distributed power generation that applies inverter technology, chargers for electric vehicles, and storage battery systems have been introduced to customers' equipment. These types of equipment may affect the impedance characteristics in harmonics calculation. Therefore, it is necessary to examine the influence of the characteristics of the equipment applying the inverter technology.

Extension of Harmonic Calculation

- An extension of harmonic calculation is shown in Figure 1. Inverters include LC filters for suppressing harmonics and grid-tie transformers for interconnection to the system. These circuit elements will be incorporated into the Y matrix as a harmonic calculation model. The element G for controlling the inverter is incorporated as an extended part of the node admittance matrix as a control transfer function.

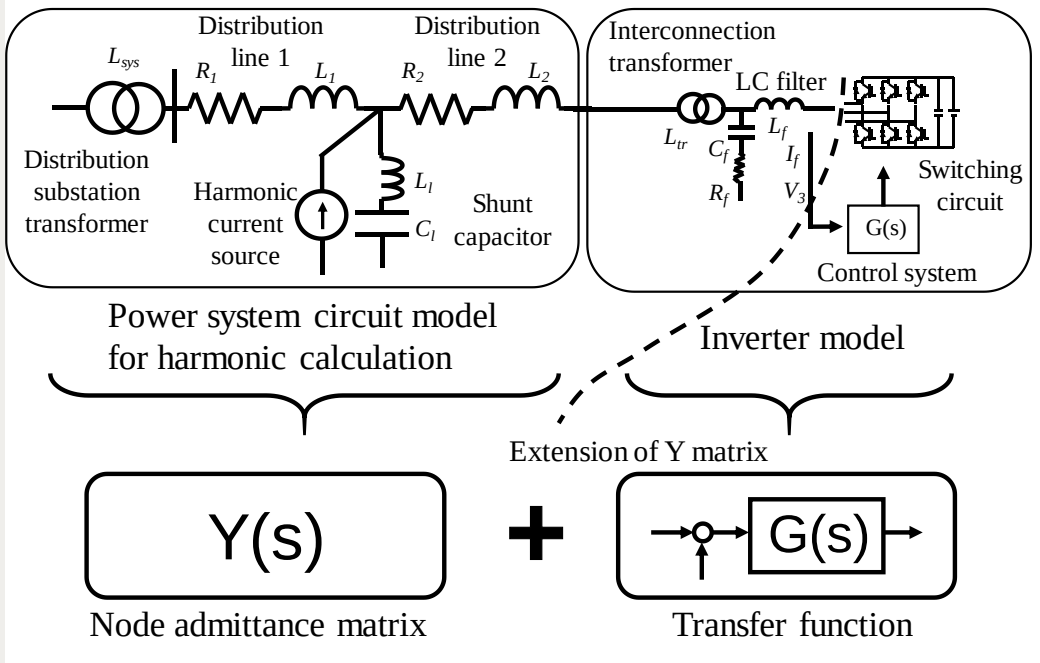

Figure 1. Extension of harmonics calculation which performs the calculation of circuit and transfer function collectively

Impact Analysis of IBRs

- Figure 2 shows frequency-impedance characteristics viewed from harmonic current sources.

- The resonance around 200 Hz is due to the shunt capacitor with a 6% series reactor. Influences of the interconnection of inverters on harmonic impedance characteristics are shown below.

(a) Without the inverter, the impedance increases monotonously at frequencies above 210 Hz.

(b) In the gate block of the inverter, the impedance increases in the range of 210 Hz to 881 Hz and decreases in the area exceeding 881 Hz.

(c) During inverter operation, it can be confirmed that the impedance stands sharply in the range of 1,110 Hz to 1,371 Hz.

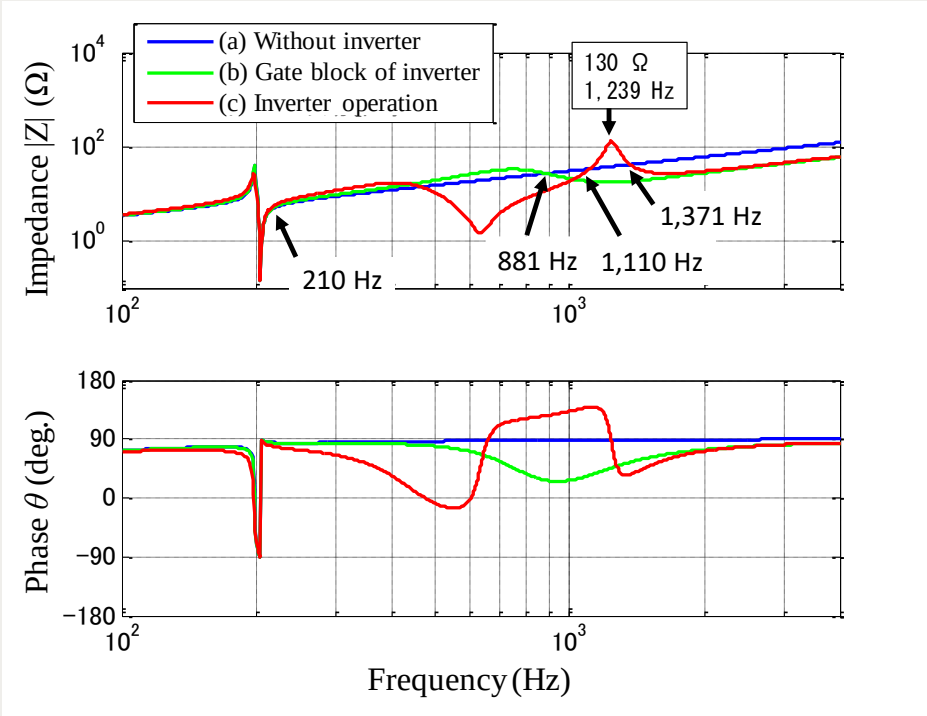

Figure 2. Frequency-impedance characteristics viewed from harmonic current sources

Reference

- Naotaka Okada, "Extension of Harmonic Calculation Considering Grid-Connected Inverter", CIRED 2021 Conference, Sep. 2021.

Instability Analysis of IBRs

- By using the extension of harmonic calculation, figure 3 shows open loop transfer functions of the inverter feedback control.
- Get frequency and open loop gain when a phase is 180 degrees. Based on experimental results shown in figure 4, voltage distortion can see at the frequency where the gain exceeds 0 dB.

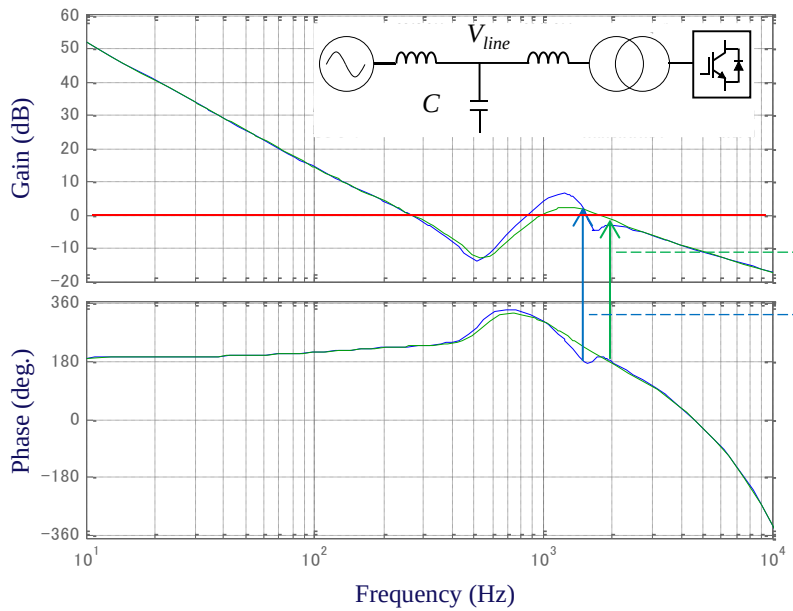

Figure 3. open loop transfer functions of the inverter feedback control

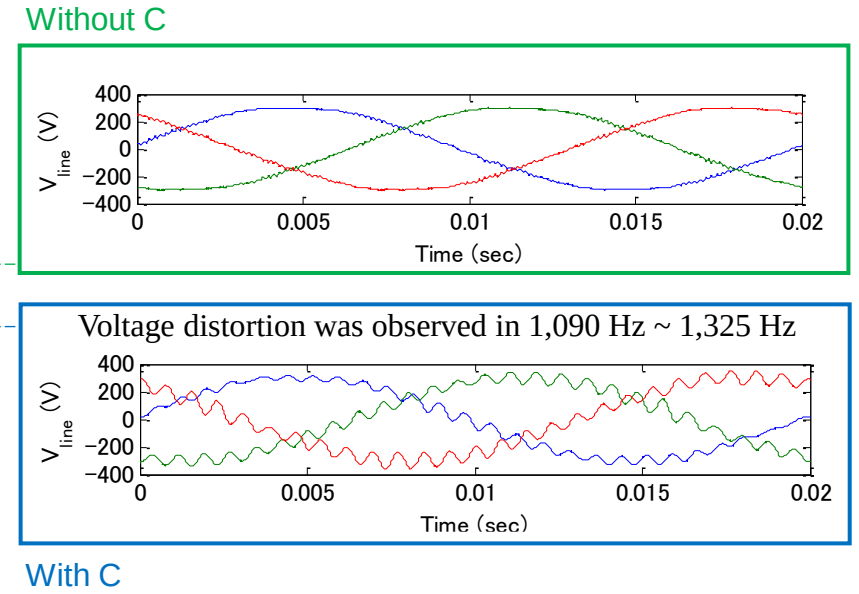

Figure 4. Experimental results

Reference

- Naotaka Okada, Kentaro Fukushima, Kenichiro Sano, "A Method to Consider Voltage Distortion Caused by Interaction Grid-Connected Inverter and Distribution System", 2020 23rd International Conference on Electrical Machines and Systems (ICEMS), November 2020.