Analysis of Reactive Power Loss Index for Evaluating Voltage Stability under High Penetration of Inverter-Interfaced Power Sources

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Introduction

In recent years, the deployment of renewable energy sources (RES), such as photovoltaic and wind power generation, has been increasing in electricity generation due to the growing concerns on the global warming CO_2 emissions during electricity generation. In Japan, this trend is expected to continue to achieve the carbon neutrality by 2050.

The paper examines the power transmission characteristics from the viewpoints of reactive power loss in a single-inverter infinite bus system especially focusing on the reactive power loss index [1]. By deriving the relationship between active power and reactive power loss, the physical meaning of the reactive power loss index is examined in paper. A sample study shows that the reactive power loss index is an effective indicator for evaluating voltage stability.

System model and derivation of the equations for the reactive power loss index

This paper analyzes the reactive power loss index for an inverter in the single- inverter infinite-bus system shown in Fig. 1. Its characteristics, in case that active power is transmitted from the inverter, are represented by the P–V curve, as shown in Fig. 2. Point A on the P–V curve, at which the inverter active power is gets its maximum, is generally referred to as the nose, and the inverter output cannot be increased further due to the voltage stability [2]. Therefore, in this paper, the point is regarded as the limit of inverter penetration, and the reactive power loss index corresponding to that point is analyzed.

Equation (1) defines the reactive power loss index L_Q [1]. Equation (2) shows the reactive power loss index $L_{Q,\ nose}$ at Point A in Fig. 2. Equation (2) shows that it is determined by the R/X ratio of the looking-back impedance and the inverter power factor cos φ where parameter x denotes the normalized reactance $1/\sqrt{(R/X)^2+1}$ [2].

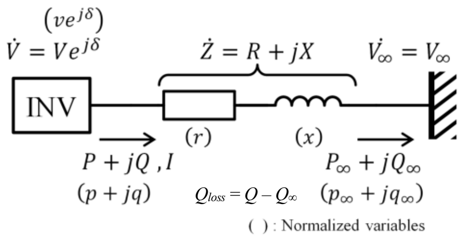

Figure 1 Power system model under study.

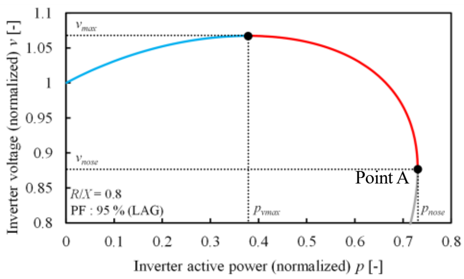

Figure 2 Example of p-v curve (R/X = 0.8, PF: 95% LAG).

$$L_Q = Q_{loss}/P \quad \cdots (1)$$
$$L_{Q,nose} = x/\cos\varphi \quad \cdots (2)$$

Reactive power loss index and stability limit

The reactive power loss index sharply increases as the operating points of an inverter approaches its nose. Figure 3 shows the reactive power loss index at the nose $L_{Q,\ nose}$ for R/X ratio of 0 to 1.0, corresponding to five inverter power factor cases-- 100%, and 80% and 90% lagging or leading. As can be seen in Fig. 3, the reactive power loss index $L_{Q,\ nose}$ varies between 1.25 and 0.7; to avoid reaching the stability limit, the reactive power loss index should be kept than 0.7 in the case.

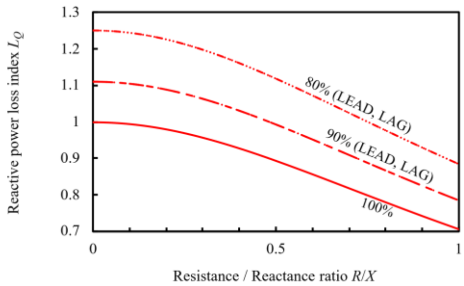

Figure 3 Relationship between the R/X ratio and the reactive power loss index at various inverter power factors.

Acknowledgement

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