Study on Small Signal Stability Based on a Synchronous Generator Model with Field Mutual-leakage Reactance

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Keywords：synchronous machine, field mutual-leakage reactance, Canay reactance, small signal stability, PSS

Modeling of electrical characteristics of synchronous machine for power system stability is based on R.H.Park's formulation of two-reaction theory, and has been established nowadays.

However, the conventional modeling of generator is known inadequate to be adopted for cases where the detailed behavior of field current has important role. I.M.Canay has proposed a field mutual-leakage reactance called Canay reactance, X_{rc} corresponding to mutual-leakage flux existing between field winding and d-axis damper winding that has not been considered in the conventional model. Using the d-axis equivalent circuit of synchronous machine with the Canay reactance (called "new generator model" hereafter), the behavior of field current can be simulated as consistent with measured test results such as sudden short circuit test.

The authors investigated the effects of "new generator model" of a round rotor generator and a salient pole generator both with AVR and PSS on small signal stability using single-machine-to-infinite bus power system model.

The results of detailed eigenvalue analysis have shown that in case of round rotor generator such as fossil-fired or nuclear generator, "new generator model" predicts a little poor damping compared with the conventional generator model. On the other hand, in case of salient pole generator such as hydro generator, "new generator model" predicts a little good damping compared with the conventional generator model.

The d-axis stator flux is written by equation (1) using operational reactance and field transfer function. The authors proposed a simple compensation transfer function that can compensate shunt ratio of field current in rotor circuit to meet "new generator model" using conventional generator model. This transfer function is lead-lag function that consists of damper time constants $T_{kd\ Canay}$ of "new generator model" in numerator and damper time constant $T_{kd\ Conventional}$ of conventional generator model in denominator.

The validity of this compensation transfer function inserted in excitation control loop has been checked with eigenvalue calculations as well as dynamic simulations.

$$\begin{aligned}\Psi_d &= G(s)'_{Canay} E_{fd} - X_d(s) i_d \\ &= \frac{(1+sT_{kd\ Canay})}{(1+sT'_{d0})(1+sT''_{d0})} E_{fd} - X_d(s) i_d \\ &= \frac{(1+sT_{kd\ Conventional})}{(1+sT'_{d0})(1+sT''_{d0})} \frac{(1+sT_{kd\ Canay})}{(1+sT_{kd\ Conventional})} E_{fd} - X_d(s) i_d \\ &= G(s)'_{Conventional} \frac{(1+sT_{kd\ Canay})}{(1+sT_{kd\ Conventional})} E_{fd} - X_d(s) i_d\end{aligned} \quad (1)$$

The authors also reviewed the values of Canay reactance for round rotor generators reported in literatures. The estimated maximum value of Canay reactance, $X_{\max}$, is defined by authors as equation (2). It was found that all of nine samples of Canay reactance correlate good with $X_{\max}$ as shown in Fig.1. It is found from Fig.1 that the value of Canay reactance has tendency to approach $X_{\max}$ for large value of $X_{\max}$, and to become smaller than $X_{\max}$ for small value of $X_{\max}$.

This indicates possibility in estimating the value of Canay reactance in some measure for stability analysis when exact value of Canay reactance cannot be given for some reasons.

$$\frac{1}{X_{\max}} \triangleq \frac{1}{X''_d - X_l} - \frac{1}{X_{ad}} = \frac{(X'_d - X''_d)}{(X_d - X_l)(X''_d - X_l)} \quad (2)$$

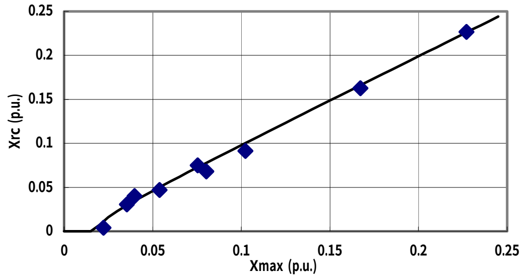

Fig.1 Correlation with estimated maximum value, Xmax