A Study on Load Frequency Control of AC-DC Power Transmission Using Fuzzy Control

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With an increasing demand for electric power, the electric power system becomes more and more complicated. Therefore, the supply of electric power with stability and high reliability is required. Then, high-voltage direct current (HVDC) power transmission that can permit the connection of two power systems having different power frequencies and realize fast and precise power flow control is regarded as important⁽¹⁾.

This paper presents a control method to improve the characteristics of load frequency control (LFC) of AC-DC transmission in power systems.

Fig. 1 shows the typical 3-area longitudinal model system studied and the conception of the proposed method in this paper. (For the details, refer to literature [2].) The proposed method⁽²⁾ is composed the following controllers.

- (1) The controller of the DC power transmission uses the TBC-type load estimation method (TLEM) and the proportional plus integral (PI) control. And, the power plants of area 1 are operated by the Governor-Free (GF).
- (2) The control signal for the power plants of the area 2 uses the output-setting control based on TLEM and the fuzzy control using a phase plane.
- (3) The signal of the area 3 uses the output-setting control based on the FFC-type load estimation (FLEM) and the same fuzzy control as (2).

Therefore, the dc power change $\Delta P_{dc}(k)$ at the time k is given by the following equations:

$$\left. \begin{aligned} \Delta P_{dc}(k) &= -U_{P11}(k) + U_{P12}(k) + r_1(k-1) \\ U_{P11}(k) &= (K_{P1} + K_{I1}/S) \Delta f_1(k), \quad i=1,2 \end{aligned} \right\} \quad \dots(1)$$

where, K_{P1} is the proportional gain of the area i . K_{I1} is the integral gain of the area i . Δf_1 is the frequency deviation of the area i . r_1 is the output-setting signal of TLEM of the area 1.

Further, the control signals $U_2(k)$ and $U_3(k)$ considering the computation time-delay of one sampling period for the power plants of areas 2 and 3 are given by the following equations:

(a) Block diagram of model system.

(b) Conception of proposed method.

Fig. 1 3-area LFC model system of AC-DC transmission.

$$U_2(k) = r_2(k-1) + U_{F2}(k-1) \quad \dots(2)$$

$$U_3(k) = r_3(k-1) + U_{F3}(k-1) \quad \dots(3)$$

where, r_2 is the output-setting signal based on TLEM of the area 2. r_3 is the output-setting signal based on FLEM of the area 3. U_{Fi} is the fuzzy control signal of the area i .

Where, the gains K_{P1} , K_{I1} and turning parameters of the fuzzy controller are designed based on [2], and the performance function J_1 is given by the following equations:

$$J_1 = \sum_{k=0}^h |\Delta f_1(k)| x_{tk}^2 \quad \dots(4)$$

(a) Response of the area 1.

(b) Response of the area 2.

(c) Response of the area 3.

Fig. 2. Responses of proposed control method. ($T_k=0.1$ s)

(a) Response of the area 1.

(b) Response of the area 2.

(c) Response of the area 3.

Fig. 3. Responses of conventional method. ($T_k=0.1$ s)

$$J_2 = \sum_{k=0}^h \{ |\Delta f_2(k)| + |\Delta P_{t1e12} + \Delta P_{t1e23}| \} \times t_k^2 \dots (5)$$

$$J_3 = \sum_{k=0}^h |\Delta f_3(k)| \times t_k^2 \dots (6)$$

$$J_{t0} = \sum_{i=1}^3 J_i \dots (7)$$

where h is the finish time of simulation. t_k is $k \times T_k$, T_k is the sampling time. ΔP_{t1eij} is the power flow deviation in the tie-line between area i and j .

Fig. 2 and Fig. 3 show the response characteristics under the step load disturbances that are 150MW in all areas. Where, ΔP_{Nti} is the non-reheat turbine output deviation of area i . ΔP_{Rti} is the reheat turbine output deviation of area i . The case of the proposed method is given in Fig. 2. Also, the conventional method is Fig. 3.

The conventional method is composed the following controllers^[2].

- (1) The control method of HVDC is PI control. And, the power plants of area 1 are operated by GF.
- (2) The control signal of the power plants of area 2 uses TBC.
- (3) The control signal of area 3 uses FFC.

By comparing the proposed method in Fig. 2 with the conventional method in Fig. 3, the frequency deviation of the proposed method converged faster and reduced oscillation. And, in particular, it shows that the responses of ΔP_{t1e12} and ΔP_{t1e23} in Fig. 2 have an effect of proposed method by which the area 1 is getting the electric power from the area 3 through the area 2.

Thus, the proposed method has the excellent control characteristics. (Manuscript received Oct. 30, 1995)

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