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주파수 측정방법에 따른 HVDC시스템의 응답특성

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Response Characteristic of HVDC System According to Frequency Sensing Methods

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ABSTRACT

This paper deals with the frequency sensing methods at HVDC system. The objects of frequency information in HVDC system areto fire a valve and to control a frequency of AC network. Conventionally, there are two methods to measure a frequency of AC network. The first method is to draw out from the synchronous machine and the second method is from AC network. Two methods have advantages and disadvantage each other. For the extreme case of a receiving system of zero inertia (no generation), synchronous machine is essential. In this situation, the frequency information received from the synchronous machine shaft. However, the speed of synchronous machine is oscillated when a disturbance in AC network occurs, and HVDC may be oscillated due to an oscillation speed. To solve this drawback, in this paper, new frequency sensing method is proposed. A proposed method that is use a modified curve-fitting algorithm, has a robust characteristics against a harmonics and unbalanced faults. Consequently, A proposed method is verified by PSCAD/EMTDC program and experimental test.

1. Introduction

In a weak AC system or the extreme case of a receiving system of zero inertia (no generator), a conventional inverter cannot re-start after even a momentary interruption of DC power. Therefore, in this situation, S.C(synchronous-compensator) in the receiving system is generally the only practical solution. In this situation, the objects of S.C are as follows:

1. To supply the reactive power to HVDC system in transient state.
2. To enhance the strength of AC network
3. To keep the inertia of AC network

Fig. 1 shows that a synchronous compensator the connected to AC network including HVDC. From fig. 1, the equ.1 showsthe voltage deviation rate between AC network with S.C and without S.C. This means that S.C enhance the strength of AC network.

In this situation, the frequency input of HVDC controller to control AC network frequency obtained form synchronous machine shaft. The reason of this is that frequency input signal can be lost for an extreme disturbance. Fig. 2 shows the HVDC frequency control diagram. However, frequency control structure like fig. 2 has some problems, that is, frequency input signal can be distorted when a disturbance in AC network occur. And a distorted signal can cause HVDC system instability[1]

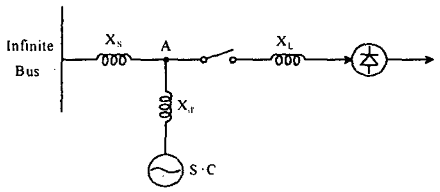


Fig. 1 Frequency sensing from synchronous compensator

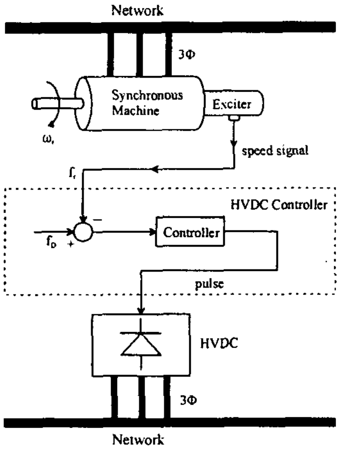
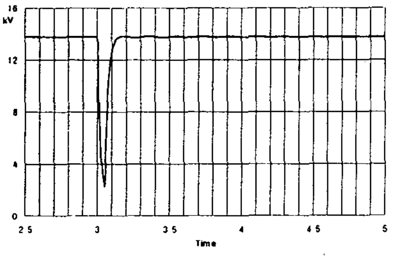
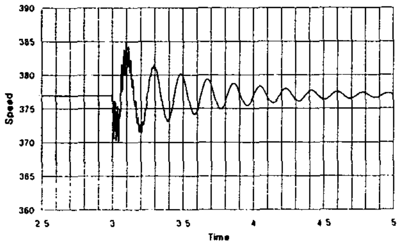


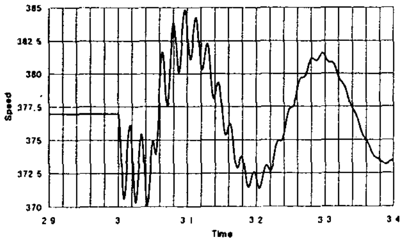
Fig. 2 Frequency sensing from synchronous machine



(a) AC voltage



(b) Speed



(c) Speed(Enlarged)

Fig. 3 Speed characteristic waveforms of synchronous compensator for 3-phase faults

Fig. 3 shows the speed characteristic waveforms in case of 3-phase faults at AC network. In fig. 3, the synchronous compensator is oscillated due to the inertia after the fault recovery. That means that HVDC can be oscillated for long time. Especially, In fig. 3 c), the speed waveform of the synchronous compensator involves the fundamental frequency for short time. This causes the fundamental resonance.

Conventionally, band-pass filter is adopted in HVDC controller to prevent this drawback. But the design of band-pass filter using in HVDC controller is very difficult. In this paper, to solve those problems, new frequency sensing method is proposed.

Since the proposed method uses a positive sequence algorithm, has a robustness and reliability against the frequency signal distorted and lost. Also, using the memory function of Digital Signal Processor solves the interruption problem of frequency signal for 3-phase fault. The proposed frequency sensing method is based on a curve-fitting algorithm, implemented by using DSP.

2. Frequency Sensing Algorithm

Fig. 4 shows the block diagram of the proposed frequency-sensing algorithm. In fig. 4, the sequence block is for the robustness against the harmonics and the memory block is for the signal reliability during faults.

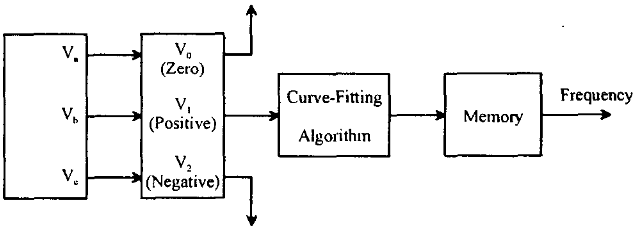


Fig. 4 Proposed frequency sensing algorithm

2.1 Single Decomposition using Sequence Theory

To solve the drawback of above described the signal losing, the pure positive sequence equation was introduced. In equ. (1)~(2), vFu, vFv and vFw are 3-phases voltage of AC network, e_ap, e_bp and e_cp are a pure positive AC voltage. And from a pure positive AC voltage, the frequency of AC network can be calculated.

$$\begin{bmatrix} e\_ap \\ e\_bp \\ e\_cp \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & a & a^2 \\ a^2 & 1 & a \\ a & a^2 & 1 \end{bmatrix} = \begin{bmatrix} vFu \\ vFv \\ vFw \end{bmatrix}$$

$$\begin{bmatrix} e\_ap \\ e\_bp \\ e\_cp \end{bmatrix} = \frac{1}{3} \begin{bmatrix} VFu - \frac{1}{2}VFv - \frac{1}{2}VFw \\ VFv - \frac{1}{2}VFw - \frac{1}{2}VFu \\ VFw - \frac{1}{2}VFu - \frac{1}{2}VFv \end{bmatrix} - \begin{bmatrix} \frac{1}{2\sqrt{3}j}(VFv - VFw) \\ \frac{1}{2\sqrt{3}j}(VFw - VFu) \\ \frac{1}{2\sqrt{3}j}(VFu - VFv) \end{bmatrix}$$

2.2 Curve-Fitting Algorithm

If the signal, $y(t)$, is distorted, then its deviation from a sinusoid can be described by an error function E.

$$x(t) = y(t) + E$$

For a least-squares method of curve fitting, the size of the error function is measured by the sum of the individual residual-squared values such that

$$E = \sum_{i=1}^{n} \{x_i - y_i\}^2$$

where $x_i = x(t_0 + i\Delta t)$ and $y_i = y(t_0 + i\Delta t)$.

$$E = \sum_{i=1}^{n} \{x_i - C_1F_1(t_i) - C_2F_2(t_i)\}^2$$

where the residual value γ at each discrete step is defined as

$$r_i = x_i - C_1F_1(t_i) - C_2F_2(t_i)$$

The error component can be described in terms of the residual matrix as follows

$$\begin{aligned} E &= [r]^T[r] \\ &= [r_1 r_2 \cdots r_n] \begin{bmatrix} r_1 \\ r_2 \\ \vdots \\ r_n \end{bmatrix} \\ &= r_1^2 + r_2^2 + \cdots + r_n^2 \end{aligned}$$

This error then needs to be minimised

$$\frac{\partial E}{\partial C} = -2[F]^T[X] + 2[F]^T[F][C] = 0$$

$$\begin{aligned} [F]^T[F][C] &= [F]^T[X] \\ [C] &= [[F]^T[F]]^{-1}[F]^T[X] \end{aligned}$$

If $[A] = [F]^T[F]$ and $[B] = [F]^T[X]$ then $[C] = [A]^{-1}[B]$

and hence

$$\begin{aligned} [A] &= \begin{bmatrix} F_1 \\ F_2 \end{bmatrix} [\, F_1 F_2 \,] \\ &= \begin{bmatrix} F_1F_2(t_i) & F_1F_2(t_i) \\ F_2F_1(t_i) & F_2F_2(t_i) \end{bmatrix} \\ &= \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \end{aligned}$$

Elements of matrix $[A]$ can then be derived as shown

$$\begin{aligned} a_{11n} &= \begin{bmatrix} F_1(t_1) \\ \vdots \\ F_1(t_n) \end{bmatrix}^T \begin{bmatrix} F_1(t_1) \\ \vdots \\ F_1(t_n) \end{bmatrix} \\ &= \sum_{i=1}^{n-1} F_1^2(t_i) + F_1^2(t_n) \\ &= a_{11n-1} + F_1^2(t_n) \end{aligned}$$

Similarly

$$\begin{aligned} [B] &= \begin{bmatrix} F_1(t_i)x(t_i) \\ F_2(t_i)x(t_i) \end{bmatrix} \\ &= \begin{bmatrix} b_1 \\ b_2 \end{bmatrix} \end{aligned}$$

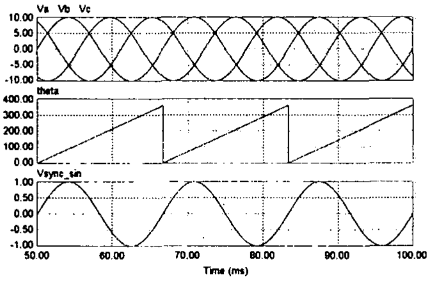
and

$$\begin{aligned} b_{1n} &= b_{1n-1} + F_1(t_n)x(t_n) \\ b_{2n} &= b_{2n-1} + F_2(t_n)x(t_n) \end{aligned}$$

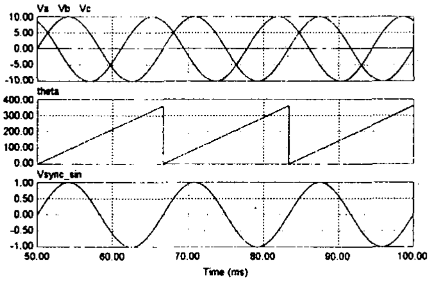
From these matrix-element equations, C_1 and C_2 can be calculated recursively using sequential data.

3. Simulation and Experiment Results

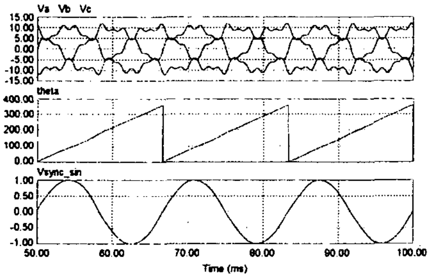
Fig. 5 (a) is the results for the case of balanced waveform, fig. 5 (b) is for the case of unbalanced case (1-phase fault)and fig. 5 (c) is for the case of another unbalanced case (2-phase fault). Fig. 5 (d) shows the result of the case of distorted waveform, that is, the waveforms involved several harmonics. And fig. 5 (e)-(h) show the result of the case of simulation considered distorted and unbalanced waveforms.



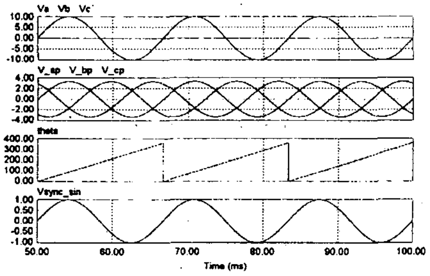
(a) AC Voltage in Steady State



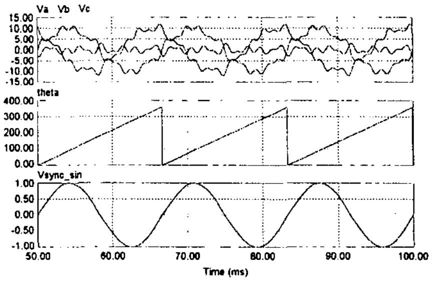
(b) Unalanced AC Voltage(Vb=0)



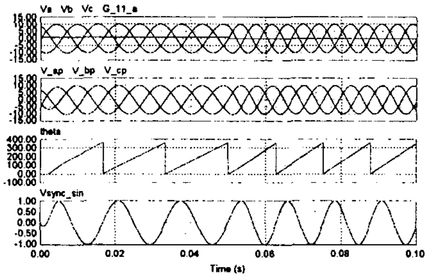
(c) Unbalanced AC Voltage
(10% of Harmonics)
(5th, 7th, and 11rh each)



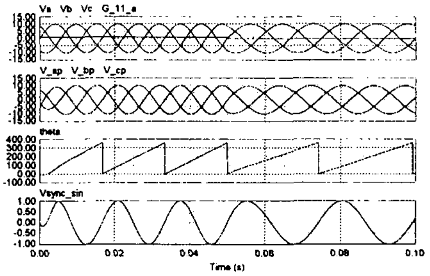
(d) Unbalnced AC Voltage
(Vb=0 and Vc=0)



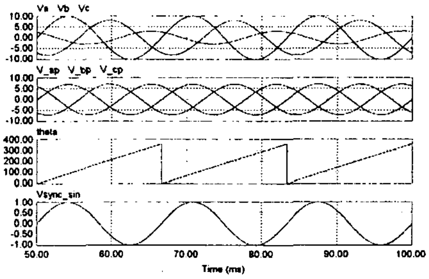
(e) Distorted and Unbalanced AC Voltage
(Vb=0 and 10% of Harmonics)
(5th, 7th and 11rh each)



(f) Frequency Changed AC Voltage
(60 Hz → 80 Hz)



(g) Frequency Changed AV Voltage
(60Hz → 40Hz)



(h) Unbalanced AC Voltage
(Va Vb Vc)

Fig. 5 Simulation results for curve-fitting algorithm

Fig. 6 (a) is the experimental 3-phase waveform in the balanced condition, at that time, the degree of the waveform and the reference waveform is shown in fig. 6 (b). And fig. 6 (c) is for the case of balanced case, fig. 6 (d) is for the case of 1-phase fault, fig. 6 (e) is for the case of 2-phase fault with harmonics. Fig. 6 (f) is the case of memory test

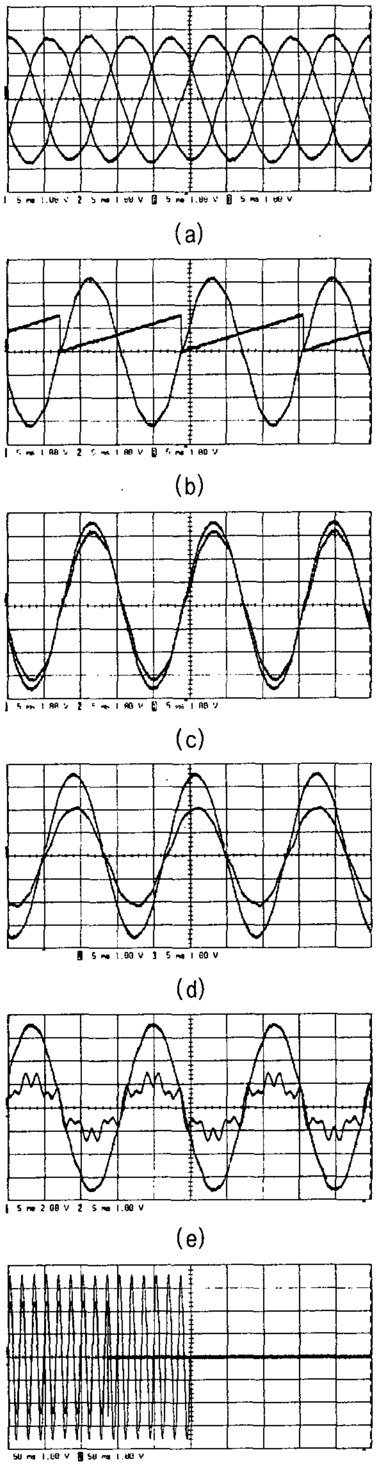

(a)
(b)
(c)
(d)
(e)
(f)

Fig. 6 Experimental results for curve-fitting algorithm

4. Conclusion

This paper deals with the frequency sensing methods in HVDC. Since the menthod that the frequency signal is derived from the synchronous compensator has several problems, the new frequency sensing method using a curve-fitting algorithm, the sequence algorithm and the memory function of DSP is proposed. The proposed method shows the reliability and robustness against AC network faults.

References

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