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High-speed Reclosing using Energy Function in Power System

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Abstract: - This paper proposes the high-speed reclosing operating method to improve for the stability in the power system. The proposed method calculates the reclosing time, taking the case of standard in which the reclosing is not done using the energy function of generator phase angle. And, the execution of reclosing time is calculated, considering the acceleration / deceleration energy of the generator in during fault. It can be expected that the delta of generator is suppressed by this optimum reclosing operation. Therefore, the system stability can be expected to improvement by carrying out the high-speed reclosing, when the fault arose. At present, it has been set at the value which seems to be optimum considering various problems in the reclosing time. However, in those methods, the system stability improvement effect can not be expected. It was demonstrated that the high-speed reclosing method have depression effect of the delta in the computer simulation.

Key-Words: - Transient stability, Reclosing, One machine infinite bus system, IEEJ WEST 10machine System Model

1 Introduction

In recently years, the photovoltaic power generation system, the wind power generator system, the micro gas turbine, the dispersed power source such as the fuel cell and independent Power Producer(IPP) without transmission line, etc seem to be increase more and more in the electric power system with deregulation and liberalization of the electric power market in Japan. And, it is also anticipated that the electricity transaction in the system becomes active the trade of the electric power which is the region monopoly until now, because the trade from another region became possible. Therefore, the power systems seem to be complicate. When the fault in the transmission line arose, whether the fault is a permanent or a temporary must be judged in such system. It is necessary to carry out the reclosing operation. At present, reclosing system for carrying out in each electric power company the automatic reclosing system is the mainstream, and it is classified according to no-voltage time after the fault and voltage class of transmission line. There are high-speed reclosing carried out in the about 20～90 cycle, medium-speed reclosing carried out in the about 2.0～20 second, low-speed reclosing carried out in about 60 seconds, etc. In addition, the following are carried out by the type of the fault which arose in phase number and system of the transmission line: Single-phase reclosing, three-phase reclosing, poly-phase reclosing, etc. The optimum system as a selection of this reclosing system considering the effect of each part for all systems on importance and generator is examined and is carried out. The reclosing operation in the system is equivalent to the case in which the multiple faults was generated, because it is equivalent to the fault once removed making to arise in the short time again. Therefore, there is some the possibility which causes the deterioration of the system condition, since the reclosing operation was carried out. The improvement effect of system stability seems to be excellent, because the no-voltage time is short by such fact for the high-speed reclosing system [1]-[4]. However, the improvement on the stabilization of the electric power system have already been reported in comparison with the case of the reclosing after the fault generation by execution timing of the reclosing operation at system stability. By until now extending report, the examination on the calculation method for the reclosing time seems to be not sufficient [5]-[7].

Then, the energy function of generator phase angle were noticed in one machine infinite bus system, and the calculating method in reclosing operation time was proposed. Then the effectiveness of proposed method was examined. In addition, the examination was carried out using the IEEJ WEST 10-machine

System Model in order to show the effectiveness by the multi-machine system [8].

2 Reclosing Operation

On the reclosing operation as the fault arose in the transmission line, high-speed reclosing, medium-speed reclosing, low-speed reclosing systems, etc. are carried out at present. In this paper, the examination is carried out from the viewpoint of high speed reclosing. Generally, the execution time is different for the every voltage class on the reclosing operation execution considering no-voltage time and generation of secondary arc current, etc. For example, they are the 50 cycles in the three-phase reclosing in the 500kV transmission line, and there is the report with 30 cycles at 275kV-187kV.However, though the reclosing operation is examined from the arc extinction time and system oscillation control plane of the secondary arc, there be seem to no a clear method. Then, calculating method for reclosing operation start time after the fault generation for the purpose of the system stability improvement is proposed, and the effectiveness is examined.

2.1 Reclosing operation method

In this paper, the condition before the fault is made to be a standard considering the relationship between potential energy and kinetic energy. Angular velocity omega was calculated from internal phase angle delta of the generator, and the reclosing operation time was calculated from kinetic energy Vk.

The energy function used in this paper is shown in following equation.

$$V_k = \frac{1}{2}\sum_{i=1}^{n} M_i \Delta\omega_i^2 \ [J] \qquad (1)$$

Here, $V = \frac{1}{2}\sum_{i=1}^{n} M_i\omega_i^2 - \sum_{i=1}^{n}\int_{\theta i0}^{\theta i}(P_{mi} - P_{ei} - R_i P_{coa})\,d\theta_i$

2.2 Model System

The model system as an object is shown in Fig. 1. In the generator, the GOV shown in Fig. 2 and the AVR shown in Fig. 3 have been installed, and it is supposed to be linked with the infinite bus model through two lines transmission line. The fault assumed the case in which it arose in generator side close point edge of the transmission line here. As a type of the fault, one-line ground fault two-line ground fault three line earth faulting, etc.

In this paper, the three line earth faulting in which the fault seemed to be the severest was made to be a standard. This time, the nonlinearity seems to strengthen on the system, when GOV and AVR, etc. were considered in the generator, since each control equipment operates after the fault.

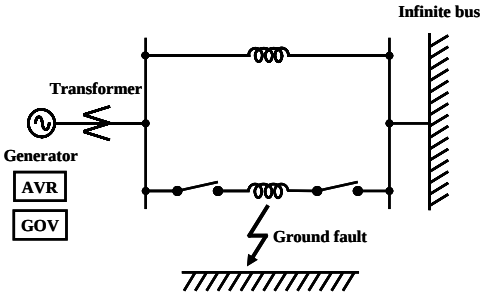

Fig. 1. One machine infinite bus system.

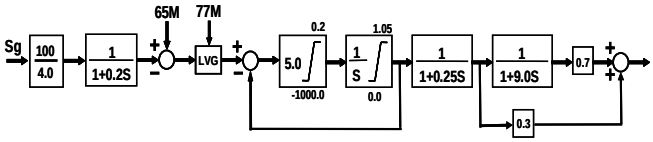

Fig.2 Block diagram of GOV.

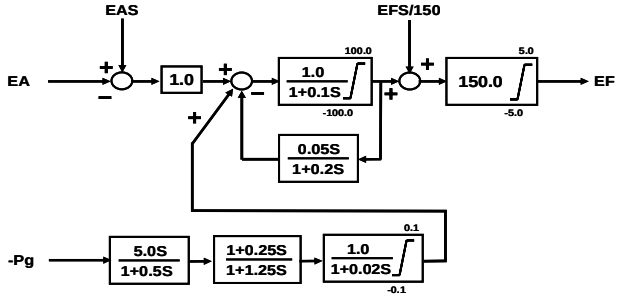

Fig.3 Block diagram of AVR.

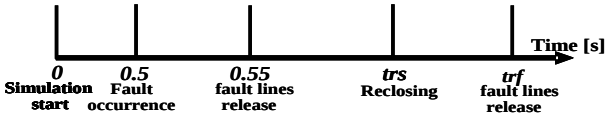

Fig. 4. Time sequence.

Line distance of the transmission line is 300km, voltage class is 500kV as eternal 3 line earth faulting that made the fault severe as a simulation condition. And, the time sequence is shown in Fig.4. The simulation is started at 0 sec, the fault is at 0.5sec and it has opened after 0.55sec in the transmission line. It is trs in the reclosing operation start time. After 0.05 seconds of trs have be made to be trf. The trf is the reclosing operation finish time. This time, the trouble transmission line has opened.

3 One-machine infinite bus system model

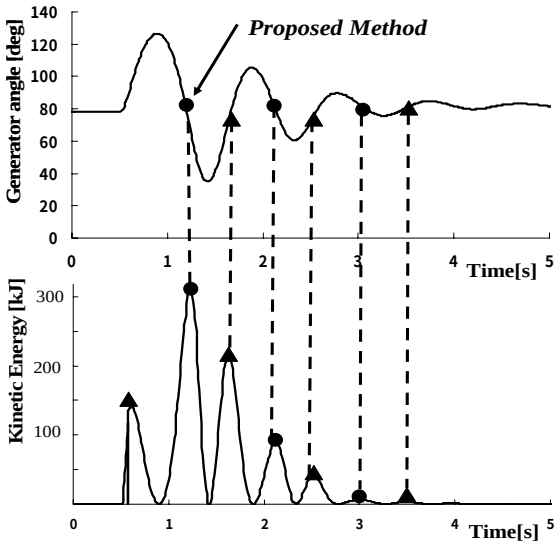

Fig.5. Correlation of kinetic energy and generator angle.

Fig.5 shows the generator internal phase angle oscillation in the case of the reclosing operation in the model system of Fig.1. There are the seven points on the value in which Vk takes the maximal value before 4 seconds, as it is shown in Fig.5. Then, the improvement effect of system stability can not be expected in case of the odd number wave (the black triangle in the figure) as a reclosing operation time, when the generator internal phase angle oscillation was considered, because Delta-omega is carrying out the acceleration, and internal phase angle delta is in the rise. In the meantime, the improvement effect of system stability can be expected, since the internal phase angle delta decelerates the reclosing operation in the site of the even wave (the black round seal in the figure). Then, the reclosing operation time was calculated, considering no-voltage time and the top of even wave of the generator phase oscillation characteristics.

Fig.6 shows the characteristics of delta in proposed method and conventional method (50cycles).It is proven that in comparison with Fig.6, the proposed method suppresses the phase oscillation, and that they are good characteristics. This proposed method is the technique which carries out the reclosing operation by the calculation of energy function. Though the reclosing operation is carried out in the first even wave, the good oscillation control effect is obtained, when the calculation was retarded, if the reclosing operation is done in second, fourth and either top of the even wave. In the meantime, system oscillation effect which is better than the even wave is not obtained, when it is carried out in the odd number wave. The case of reclosing operation in the each even number wave in Fig.7 is shown. The case of reclosing operation in the each odd number wave in Fig.8 is shown.

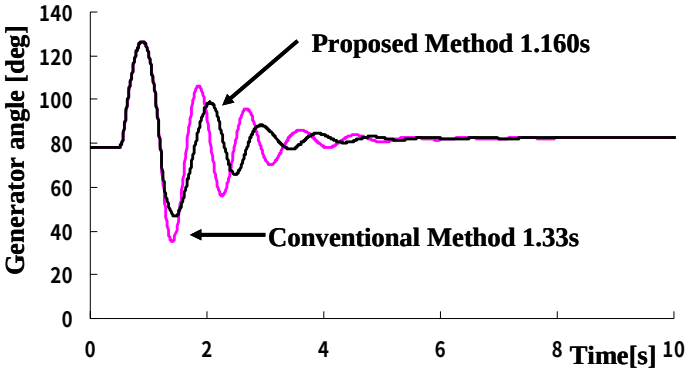

Fig.6. Characteristic comparison of each delta in the case of the different reclosing operations.

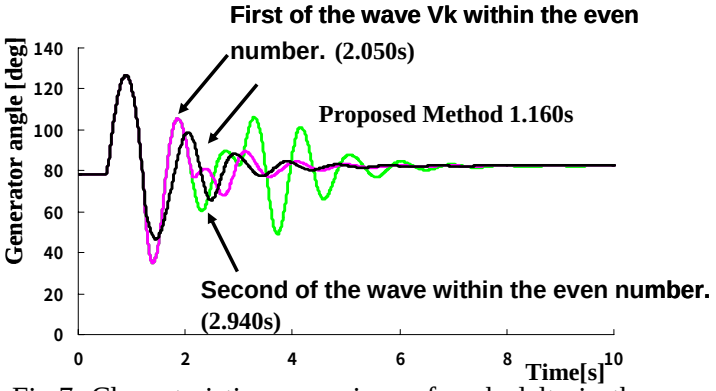

Fig.7. Characteristic comparison of each delta in the case of the even number wave reclosing operations.

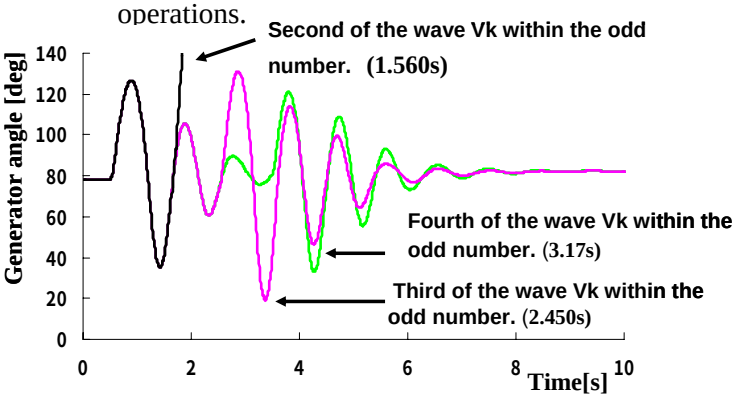

Fig.8. Characteristic comparison of each delta in the case of the odd number wave reclosing

4 Examination in the multi-machine system (IEEJ WEST10 Model system)

Until now the examination was the one machine infinite bus system, however, the actual system is the multi-machine system in which power plant and load intermingle. Then, whether high-speed reclosing operation proposed in this paper can adapt to the multi-machine system is examined. The proposal method in multi-machine system is expanded using IEEJ West 10 machine system model which is shown in Fig.9. Here, in the each generator of Fig.9, GOV shown in Fig.2 and AVR shown in Fig.10 respectively is taken into consideration. And, the examination was carried out in the each point which also showed the fault as cross section in Reference [8] in the daytime which shows the tie-line power flow condition is the rated value. In the multi-machine system, each generator shakes in proportion to the condition of each generator in fault point. Reclosing operation technique in the multi-machine system proposed in this paper is carried out by the procedure for showing in the following.

Step1: Generator internal phase angle oscillation, in the case of the no-reclosing operation, is calculated by all 10 machines.

Step2: Angular velocity deviation Delta-omega of each generator is noticed, and kinetic energy Vk is calculated.

Step3: The kinetic energy of close point edge generator of fault point is noticed, and the site as a maximum of the kinetic energy which removed the after trouble generation from the correlation with internal phase angle is calculated several points.

Step4: The time of the top of even wave of kinetic energy Vk is made to be reclosing operation time Topi-n, when generator internal phase angle oscillation delta of the close point edge is positive. And, the time of the top of odd number wave of kinetic energy Vk is made to be the reclosing operation time, Topi-n, when delta is negative.

Setp5: The earliest time required at step2 and step3 is made to be the reclosing operation time.

In Table.1, the result of calculating reclosing operation time which was each this technique for each fault point is shown. The result was not good fault point E on conventional technique [5] calculated from generator internal phase angle Delta-delta angular, velocity Delta-omega, field system voltage Delta-ef. However, it was possible that the proposed method got good characteristics from all fault point (from A to L point). Fig.11 is the Generator internal phase angle oscillation characteristics in the case of no-reclosing operation. Fig.12 is in case of reclosing operation in 50 cycles which are the conventional method. Fig.13 are characteristics in case of proposed method. It is possible to stabilize in proposed method, the characteristics in which the generator step outs in second wave in Fig.11, the case in which the reclosing operation is not carried out from Fig.12 and 50 cycle reclosing operation. In the case in which reclosing operation of Fig.11 is not carried out and 50 cycle reclosing of Fig.12, the generator step-outed in the second wave. In proposed method of Fig.13,it was possible to stabilize these characteristics.

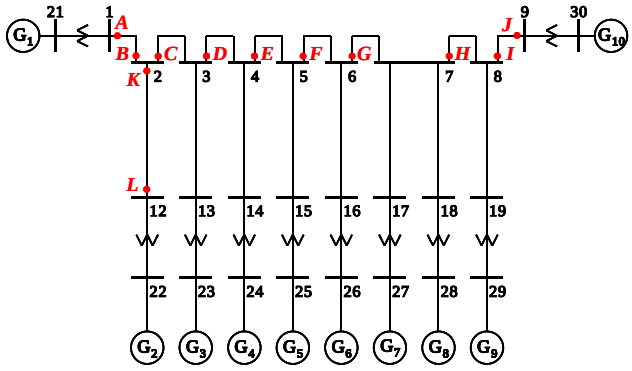

Fig.9. IEEJ WEST 10-machine System Model.

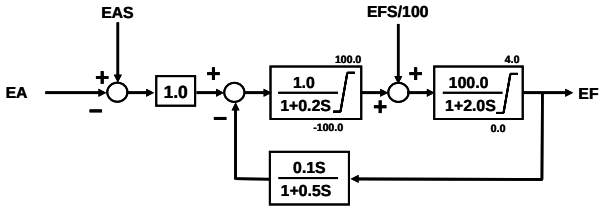

Fig. 10. Block diagram of AVR.

Table.1. Reclosing operation time with the stability improvement effect.

Fault point	Reclosing time by the proposed method [s]
A	1.85
B	1.87
C	2.05
D	2.15
E	1.21
F	1.23
G	1.21
H	1.23
I	1.79
J	1.79
K	2.09
L	1.69

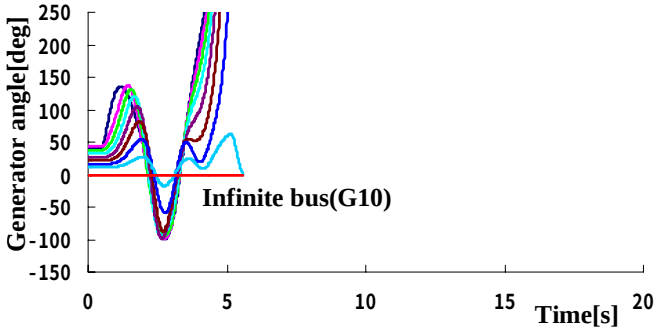

Fig.11. Characteristic of the phase angle in the case of the fault at point A(without reclosing)

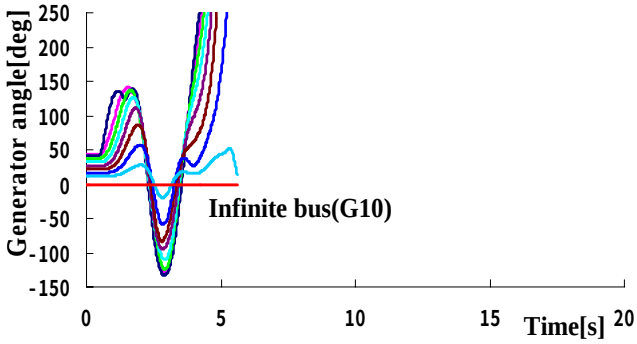

Fig.12. Characteristic of the phase angle in the case of the fault at point A (Conventional method 50cycle)

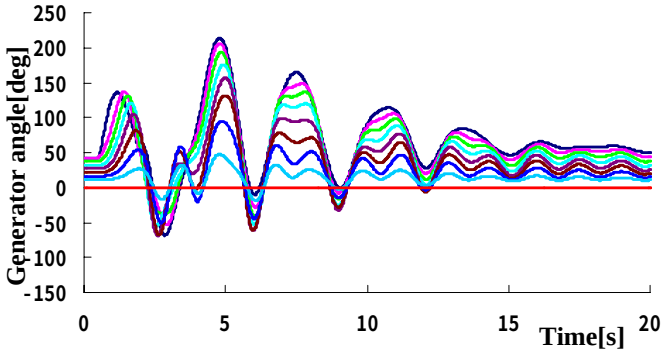

Fig.13. Characteristic of the phase angle in the case of the fault at point A(Proposed method)

5 Conclusion

In this paper, reclosing operation which considered energy function by complicating electric power system was proposed.
The effectiveness was examined using Inst. of Electrical Engineers of Japan single chance infinity generator system model, Western Japan 10 machine system model. As the result, it was confirmed that this technique was effective by various cases.

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